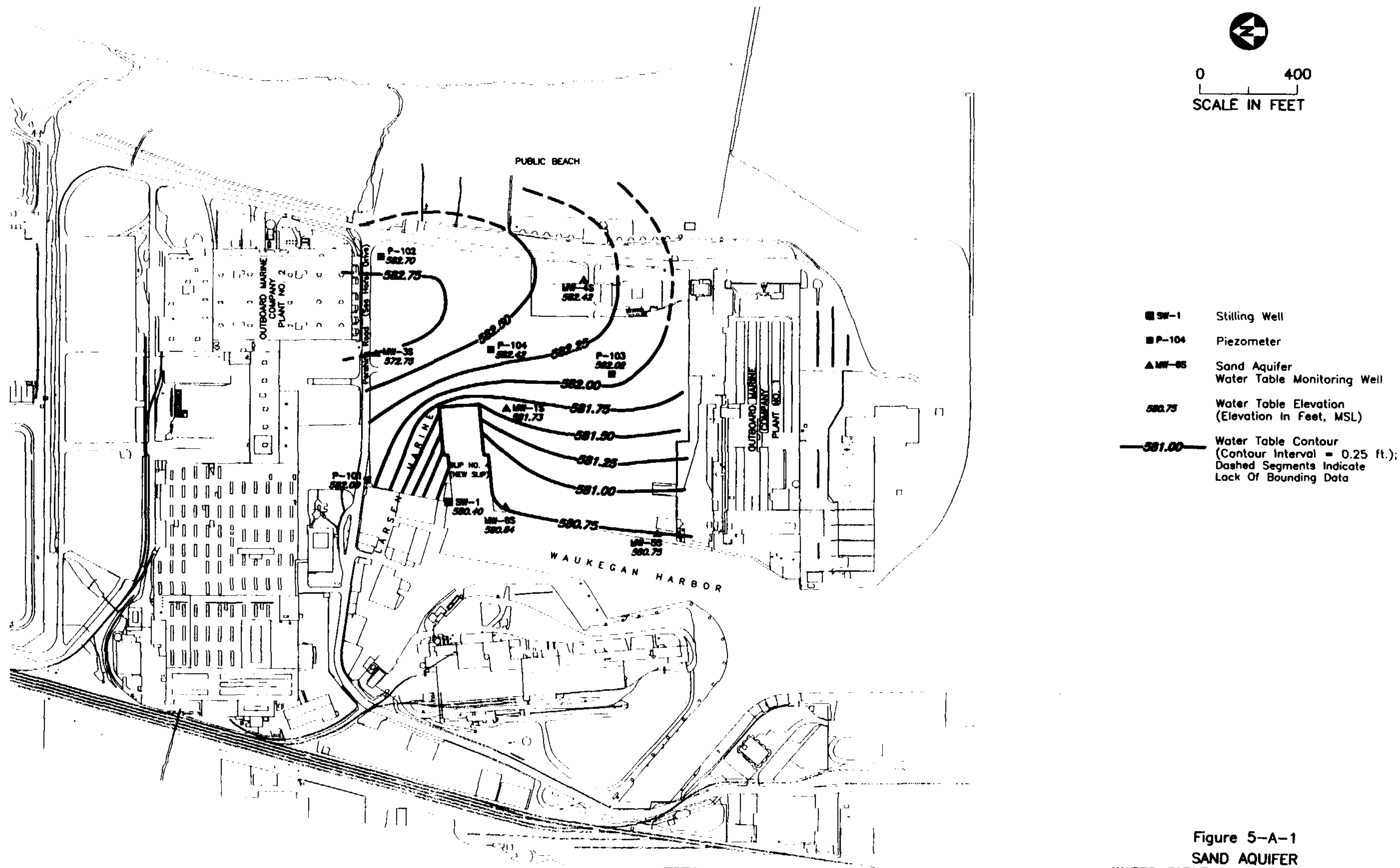
141599

Appendices

Appendix 5-A

Water Table Contour Maps



Randy Wilson C:\PROJECTS\1349005\WALK\WCP-AP15 500.00 06/20/1994 11:59:32

Figure 5-A-1
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(4/15/92)
Waukegan Manufactured Gas & Coke Plant

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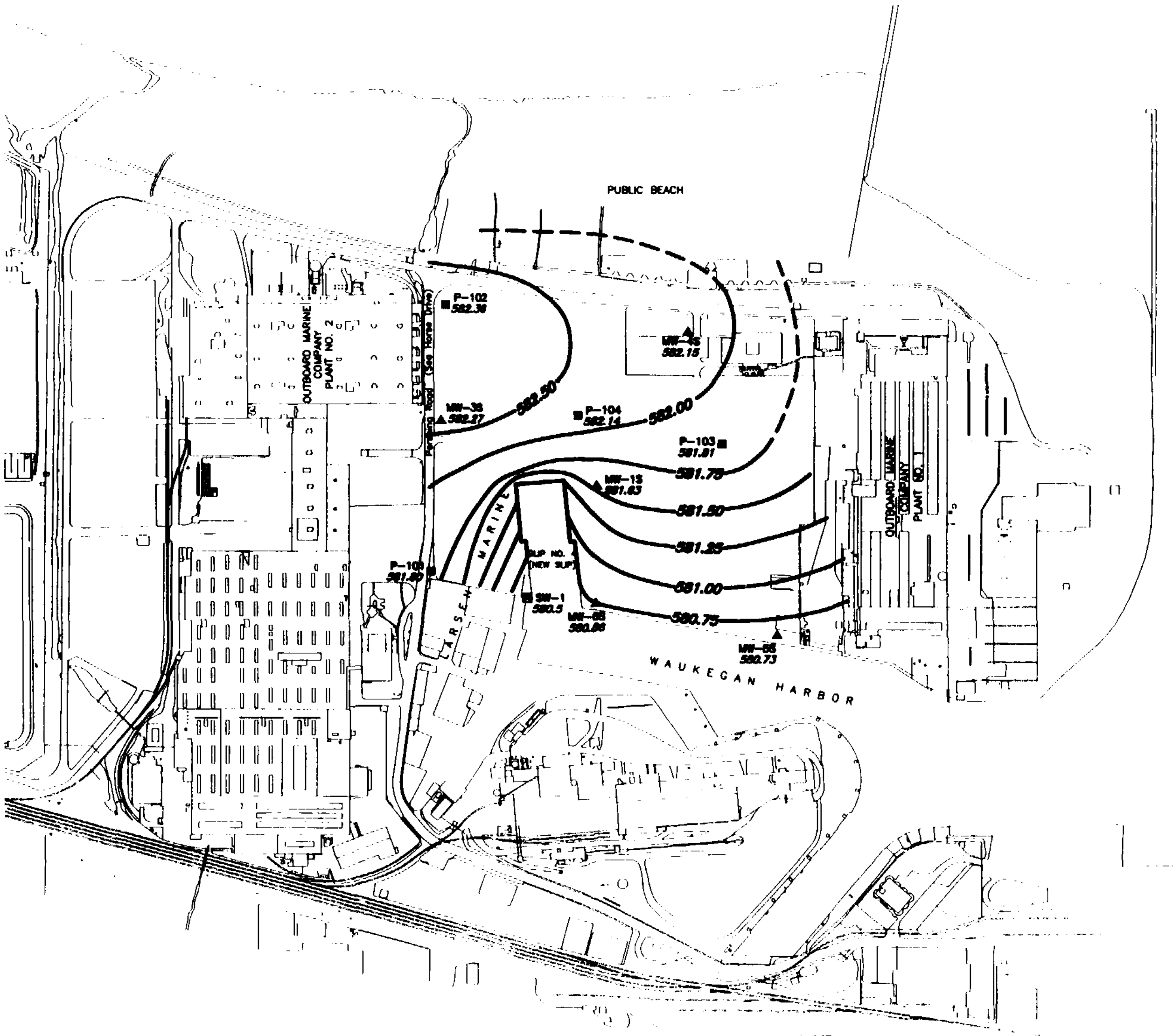

0 400
SCALE IN FEET

SW-1	Stilling Well
P-104	Piezometer
MW-6S	Sand Aquifer Water Table Monitoring Well
582.14	Water Table Elevation (Elevation In Feet, MSL)
581.00	Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

Figure 5-A-2
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(5/7/92)
Waukegan Manufactured Gas & Coke Plant

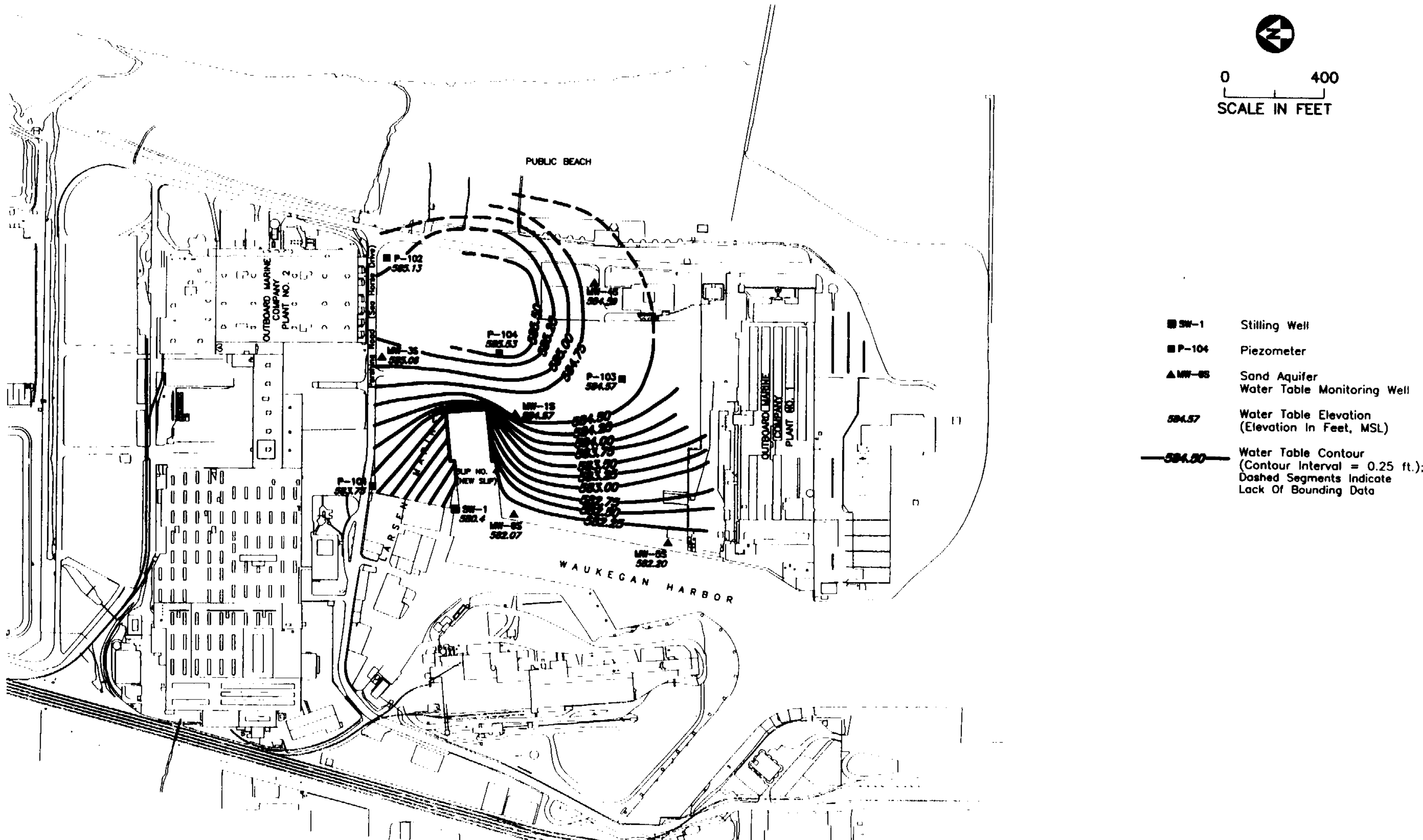

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Figure 5-A-3
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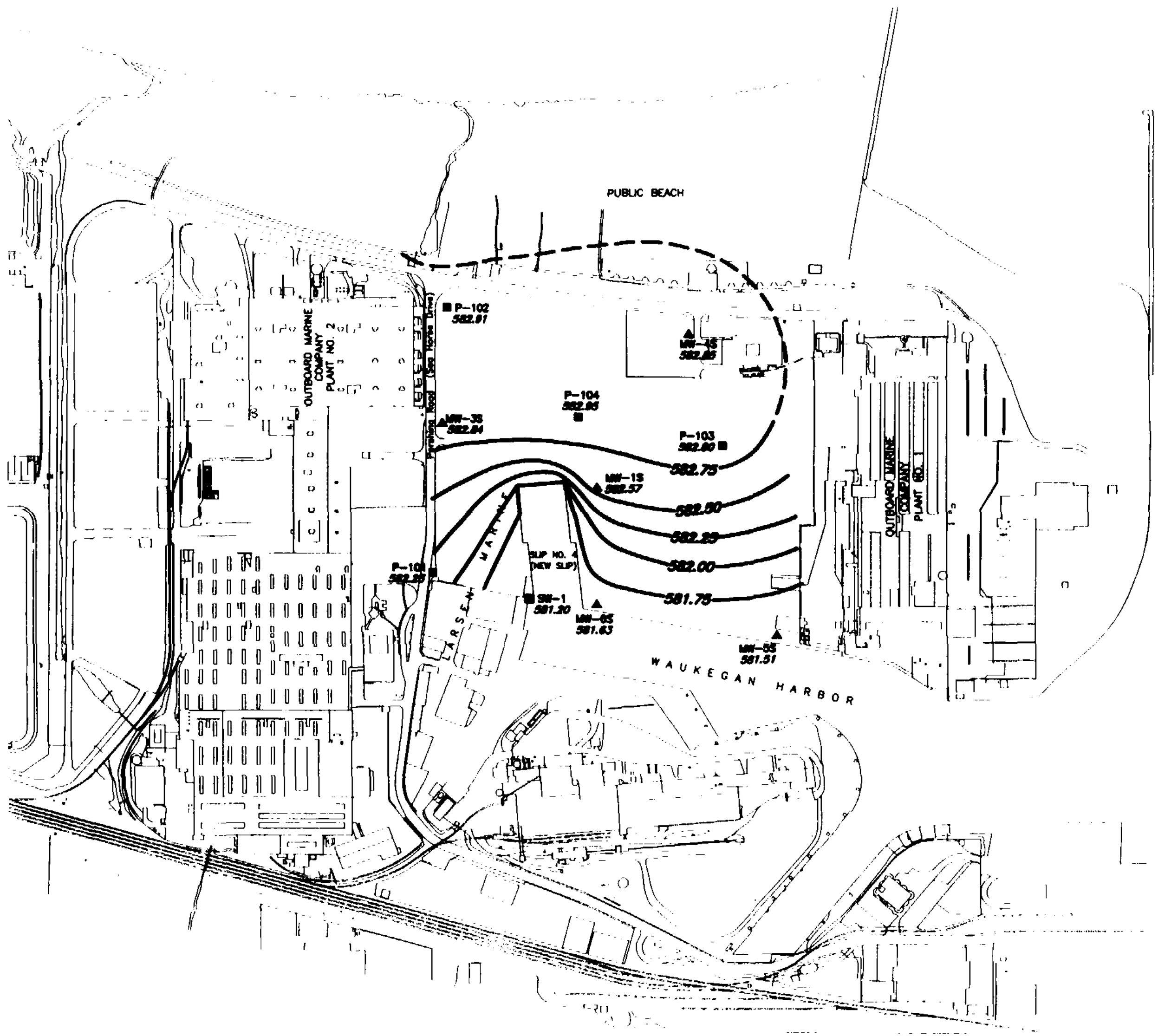
WATER TABLE ELEVATION CONTOURS
(4/15/93)
Waukegan Manufactured Gas & Coke Plant



0 400
SCALE IN FEET

SW-1	Stilling Well
P-104	Piezometer
MW-6S	Sand Aquifer Water Table Monitoring Well
582.95	Water Table Elevation (Elevation In Feet, MSL)
582.75	Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

Figure 5-A-4
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(5/21/93)
Waukegan Manufactured Gas & Coke Plant

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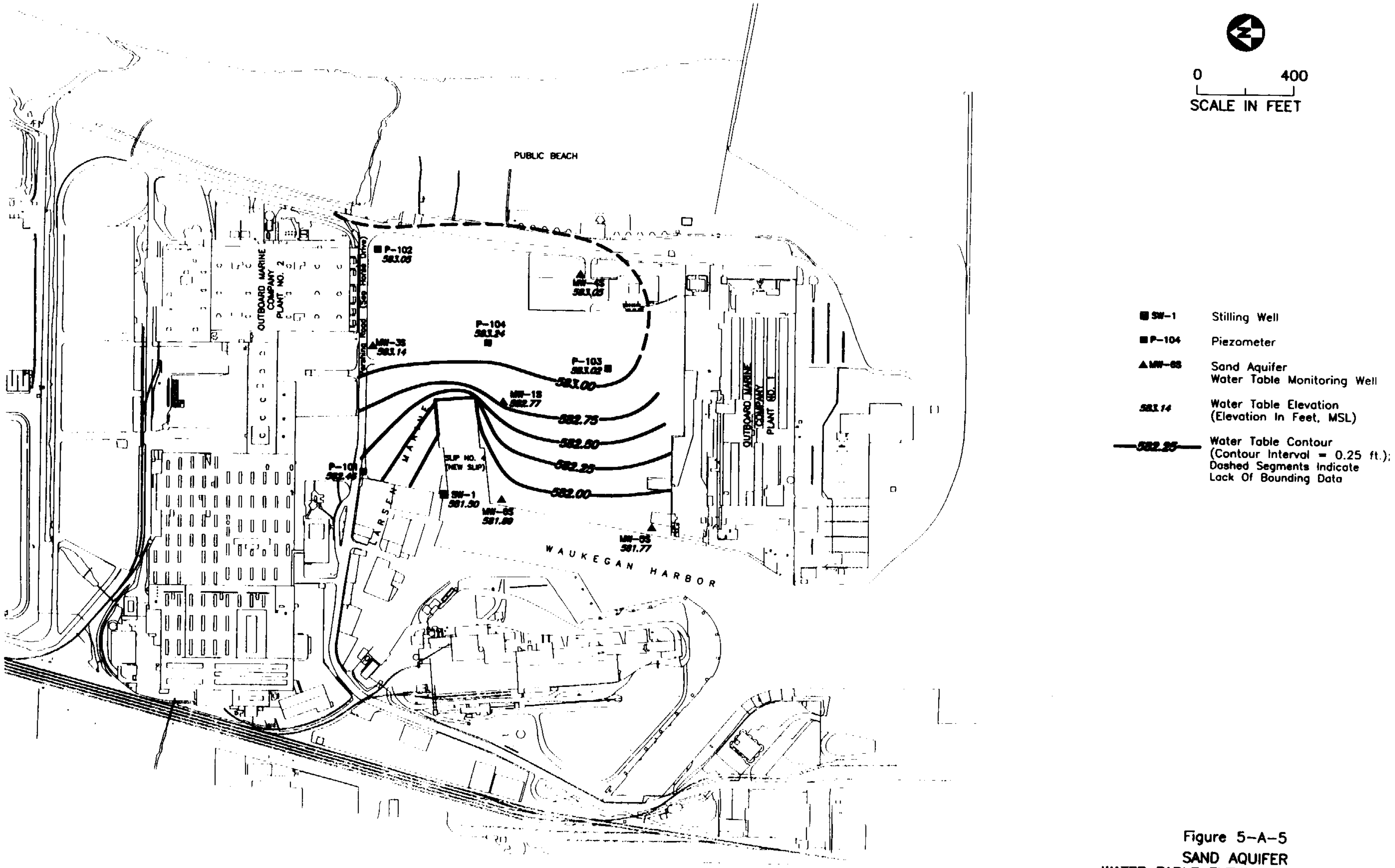

Figure 5-A-5
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(6/16/93)
Waukegan Manufactured Gas & Coke Plant

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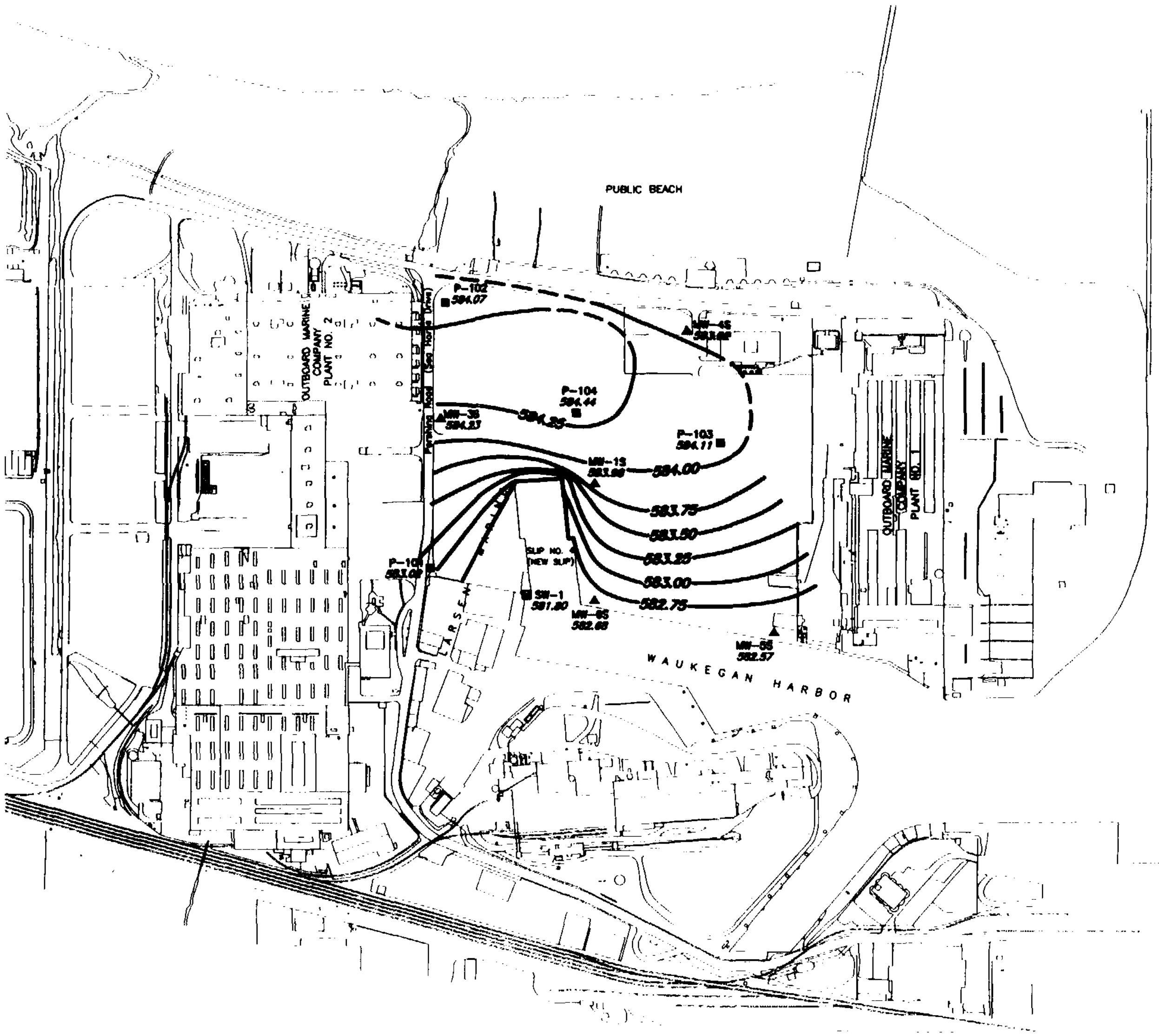

0 400
SCALE IN FEET

- SW-1 Stilling Well
- P-104 Piezometer
- MW-6S Sand Aquifer Water Table Monitoring Well
- 584.23 Water Table Elevation (Elevation In Feet, MSL)
- 584.25 Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

Figure 5-A-6
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(7/19/93)
Waukegan Manufactured Gas & Coke Plant

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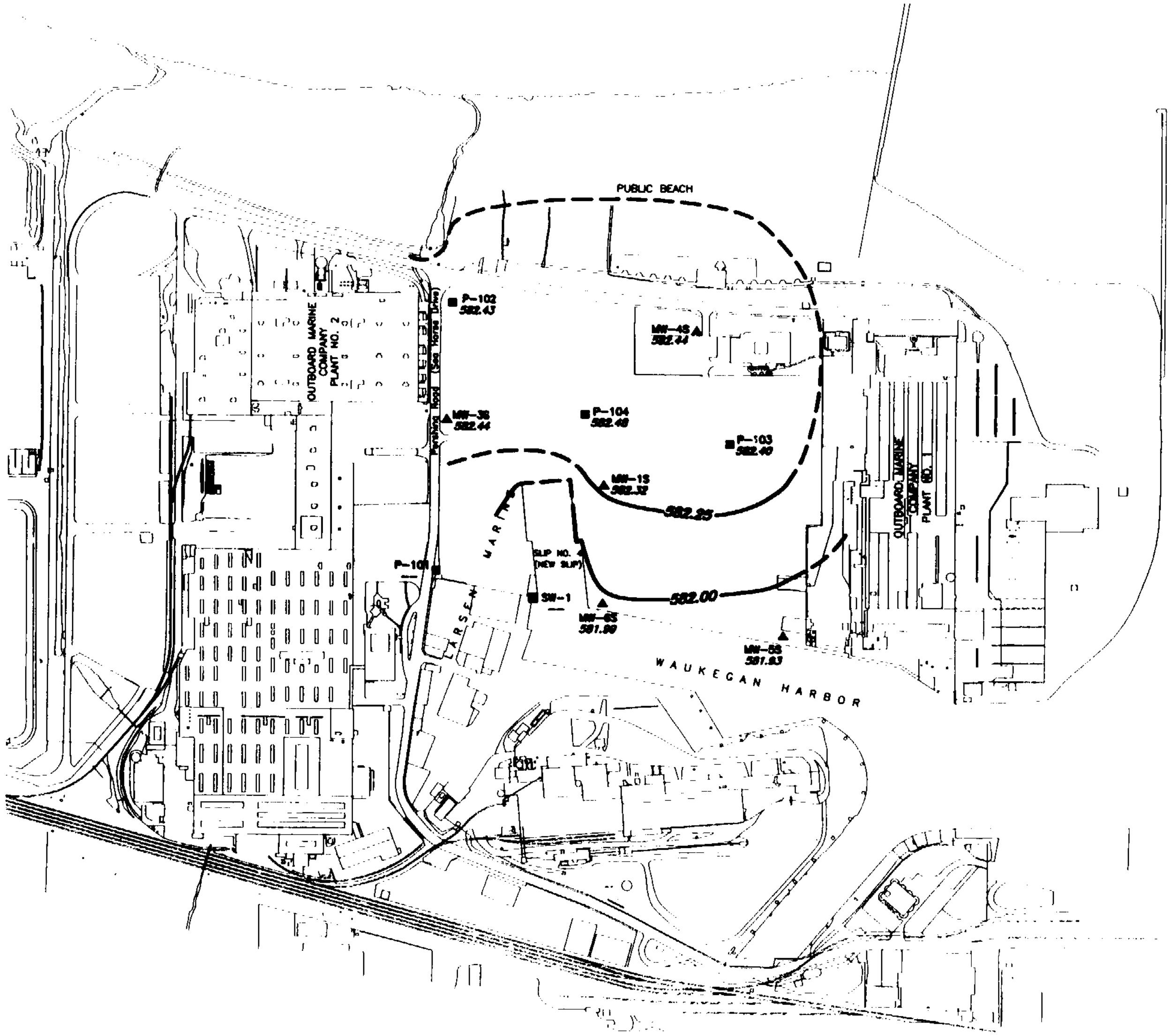

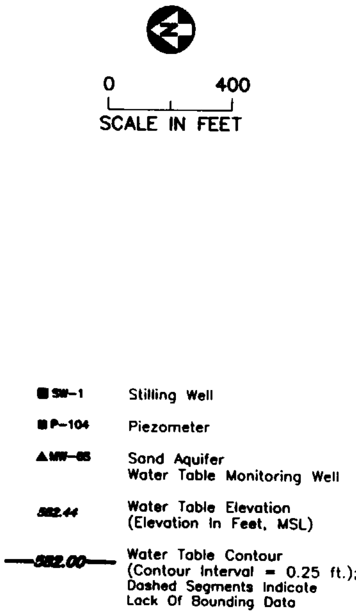

Figure 5-A-7
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(8/21/93)
Waukegan Manufactured Gas & Coke Plant

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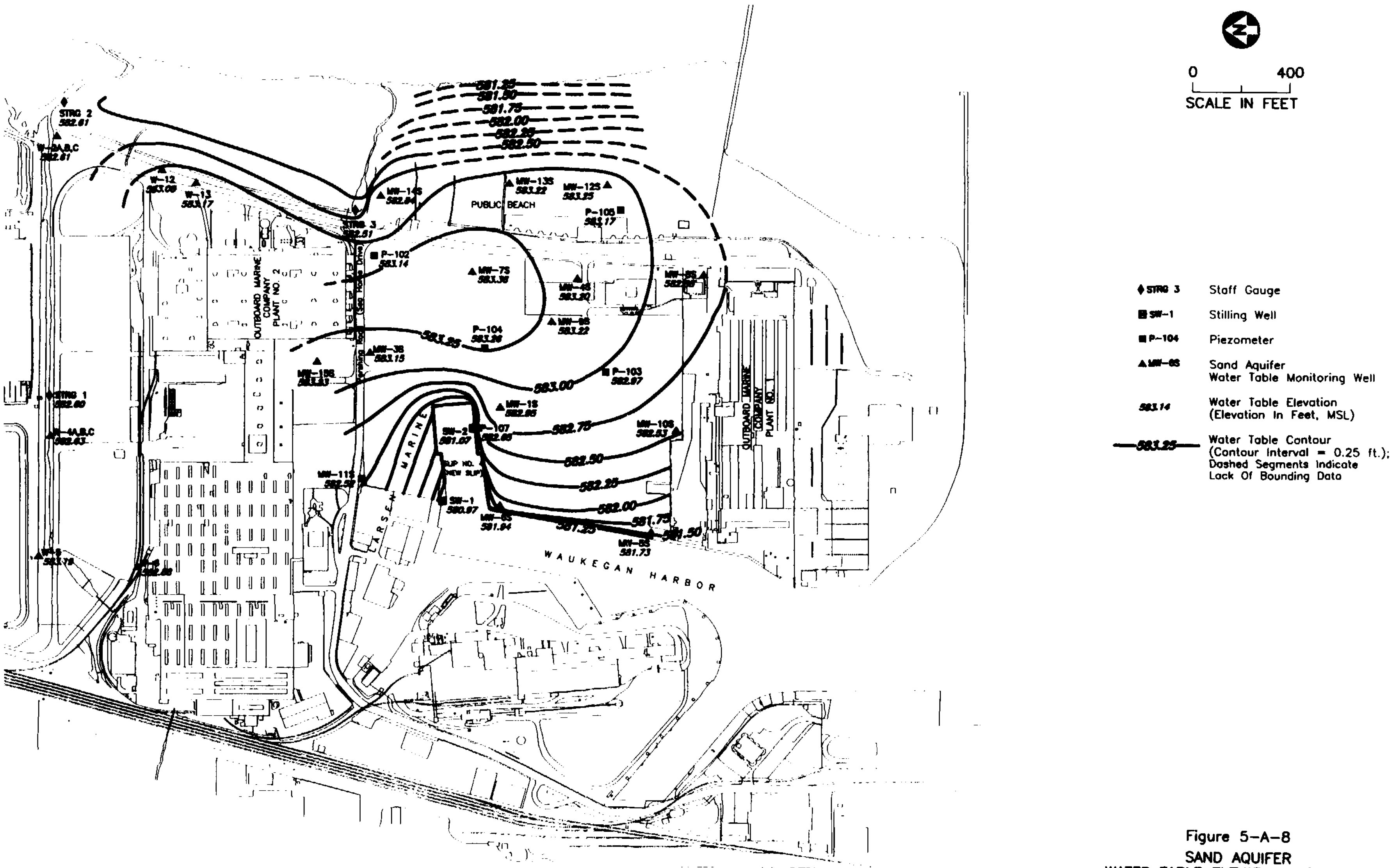

Figure 5-A-8
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(9/29/93)
Waukegan Manufactured Gas & Coke Plant

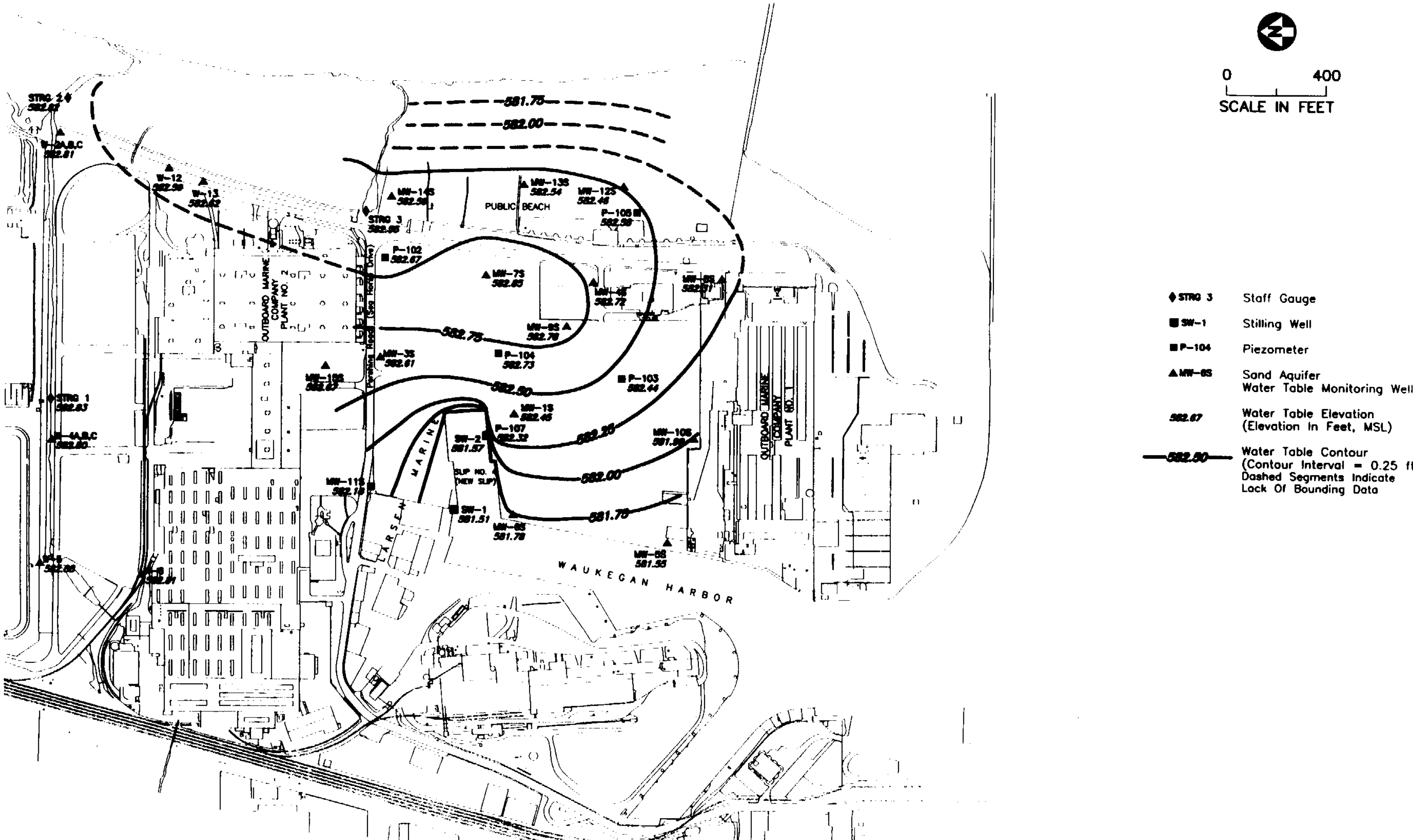

Figure 5-A-9
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(10/31/93)
Waukegan Manufactured Gas & Coke Plant

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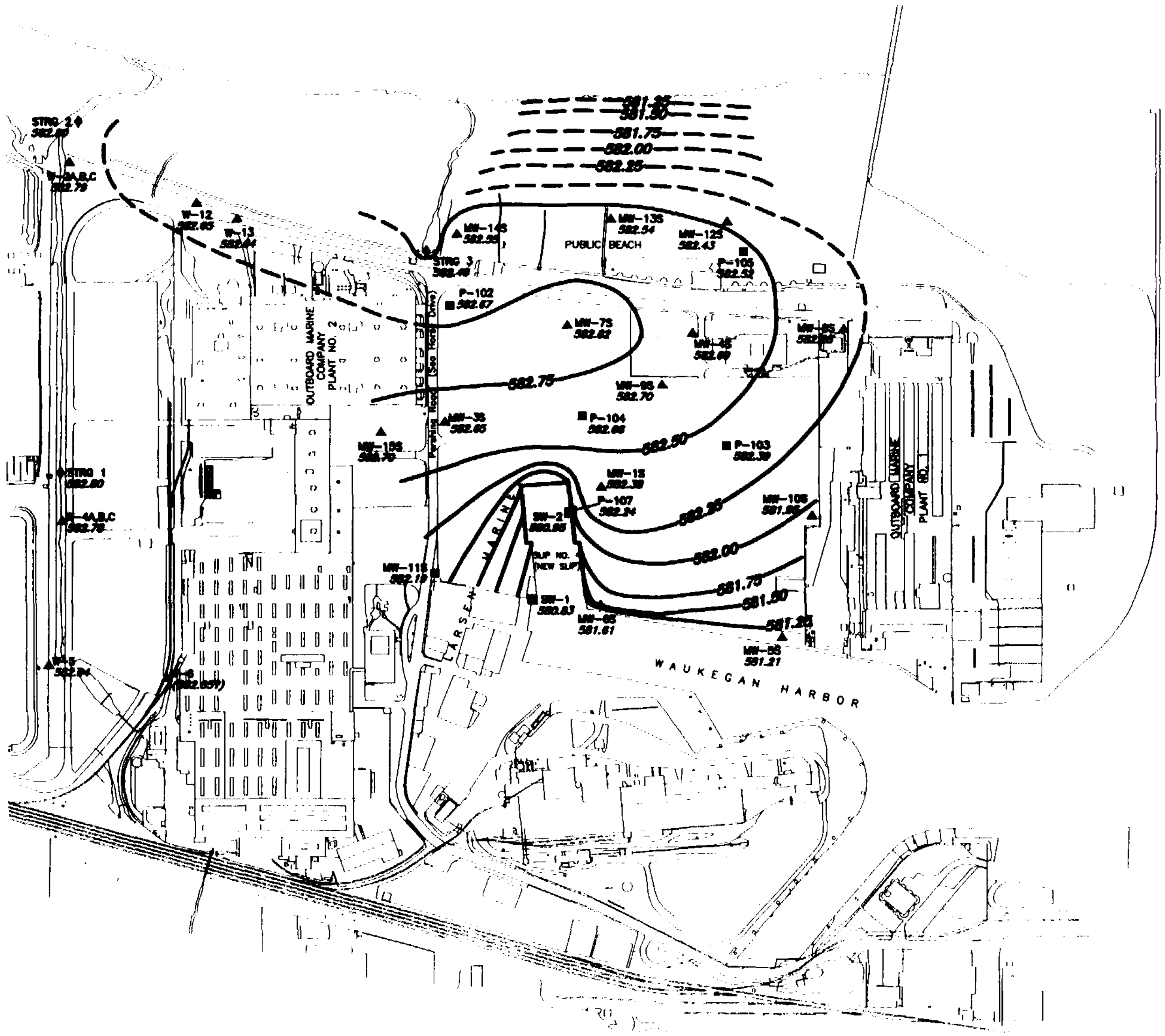


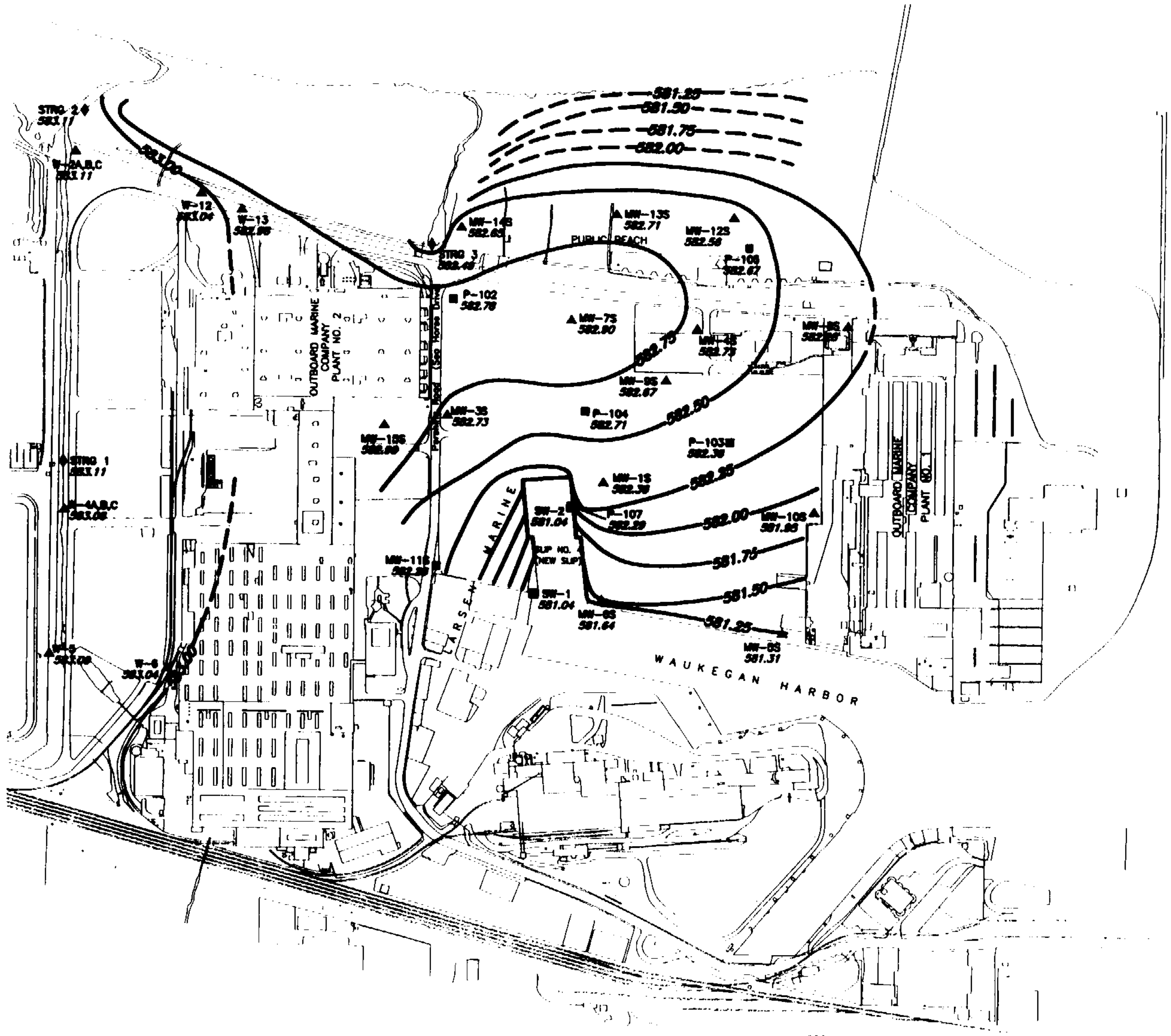
0 400
SCALE IN FEET

◆ STRG 3	Staff Gauge
■ SW-1	Stilling Well
■ P-104	Piezometer
▲ MW-6S	Sand Aquifer Water Table Monitoring Well
582.54	Water Table Elevation (Elevation In Feet, MSL)
—582.75—	Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

Figure 5-A-10

SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(11/03/93)
Waukegan Manufactured Gas & Coke Plant

Randy Wilson C:\PROJECTS\1349003\WAUK\WCP-HV03 500.00 06/20/1994 12:25:53



0 400
SCALE IN FEET

◆ STRG 3	Staff Gauge
■ SW-1	Stilling Well
■ P-104	Piezometer
▲ MW-6S	Sand Aquifer Water Table Monitoring Well
582.73	Water Table Elevation (Elevation In Feet, MSL)
—582.75—	Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

Figure 5-A-11
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(12/01/93)
Waukegan Manufactured Gas & Coke Plant

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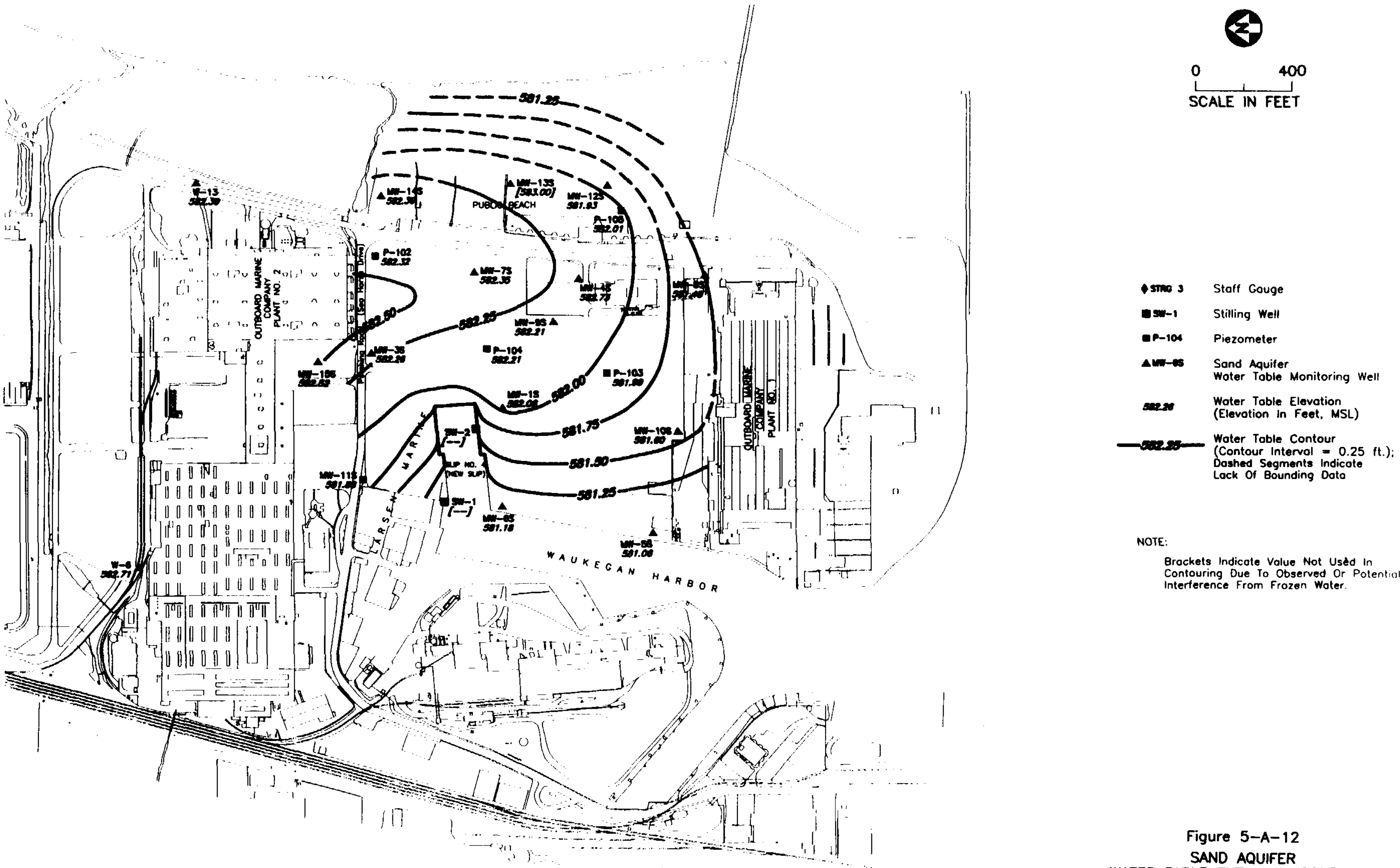

Figure 5-A-12
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(1/5/94)
Waukegan Manufactured Gas & Coke Plant

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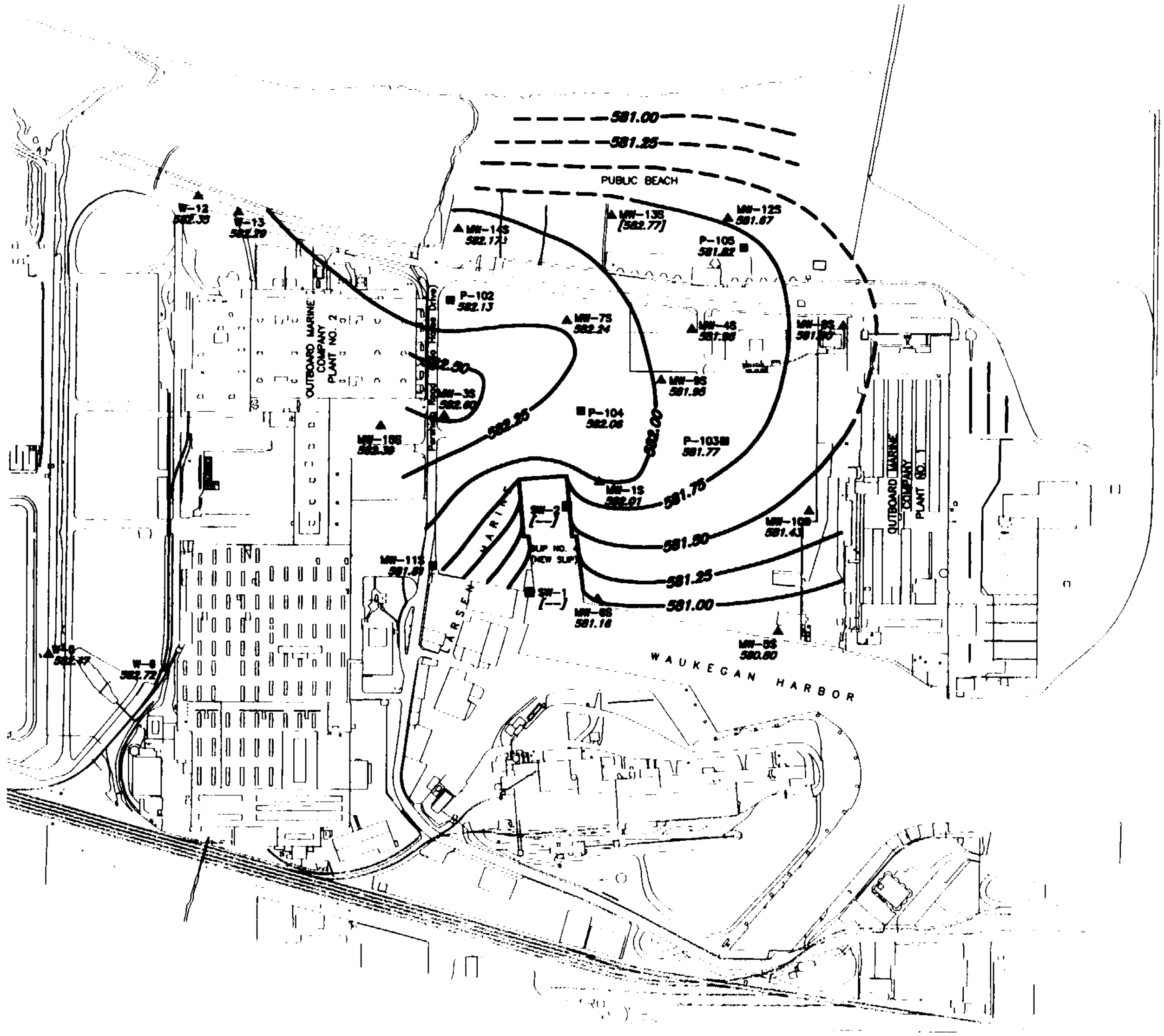


0 400
SCALE IN FEET

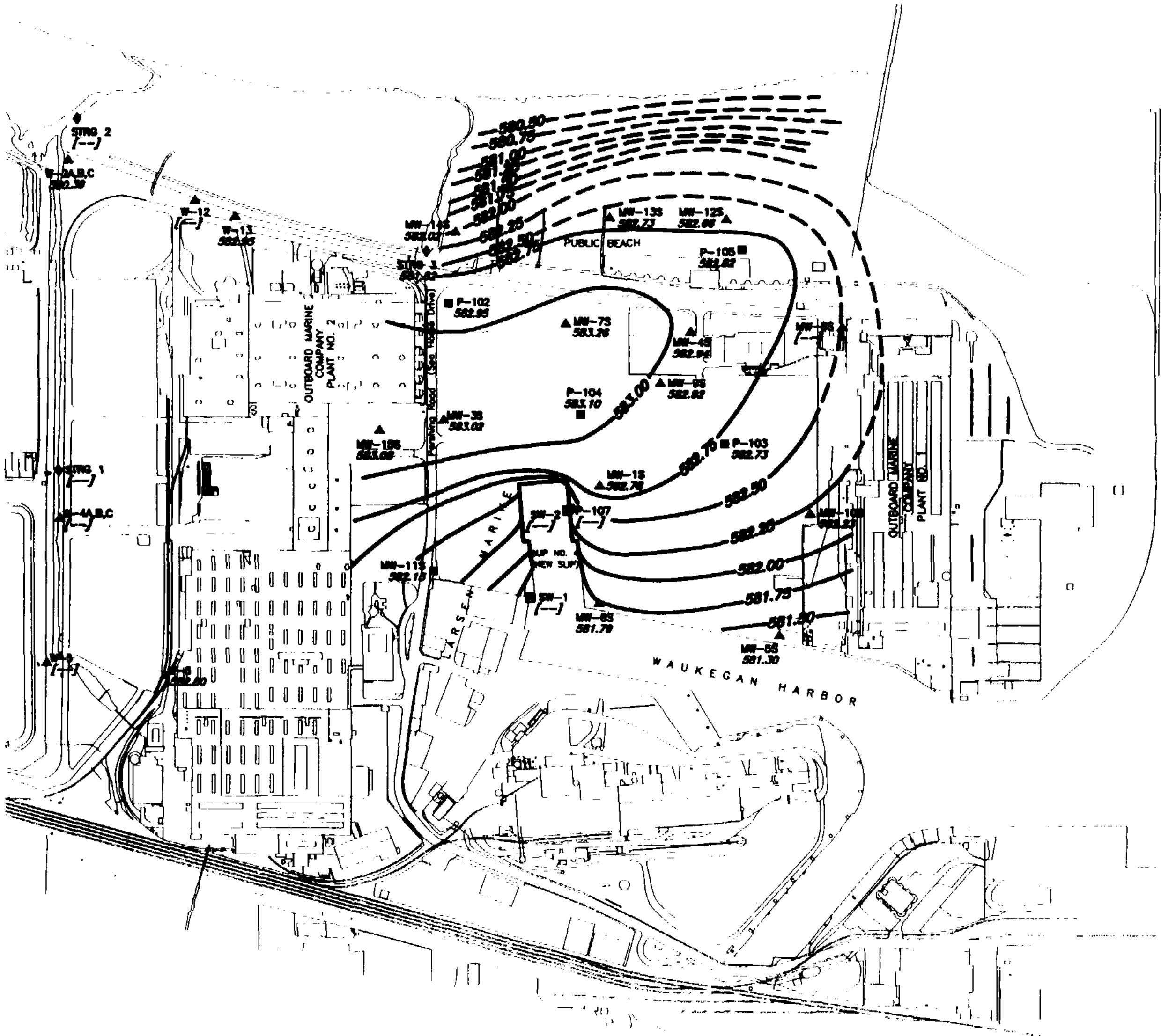
STRG 3	Staff Gauges
SW-1	Stilling Well
P-104	Piezometer
MW-8S	Sand Aquifer Water Table Monitoring Well
582.01	Water Table Elevation (Elevation In Feet, MSL)
582.25	Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

NOTE:

Brackets Indicate Value Not Used In Contouring Due To Observed Or Potential Interference From Frozen Water.

Randy Wilson C:\PROJECTS\1349003\WAUK\WCP-FB03 500.00 06/20/1994 12:33:33

Figure 5-A-13
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(2/3/94)
Waukegan Manufactured Gas & Coke Plant



0 400
SCALE IN FEET

◆ STRG 3	Staff Gauge
■ SW-1	Stilling Well
■ P-104	Piezometer
▲ MW-6S	Sand Aquifer Water Table Monitoring Well
583.14	Water Table Elevation (Elevation In Feet, MSL)
[--]	Sample Frozen When Measured
—583.25—	Water Table Contour (Contour Interval = 0.25 ft.); Dashed Segments Indicate Lack Of Bounding Data

Figure 5-A-14

SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(3/3/94)
Waukegan Manufactured Gas & Coke Plant

Randy Wilson C:\PROJECTS\1349003\WAUK\WCP-MR3 500.00 06/20/1994 12:36:01

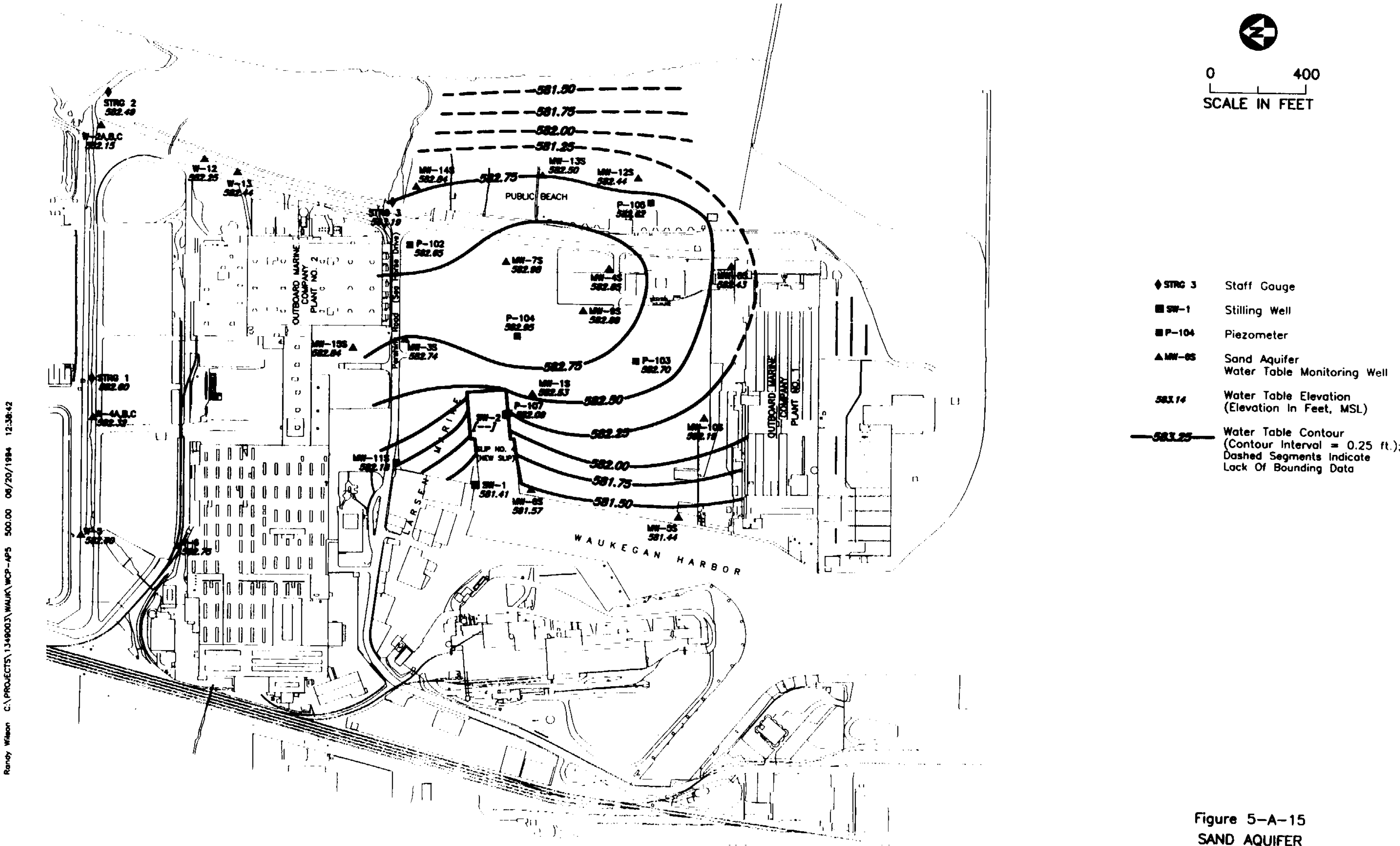


Figure 5-A-15
SAND AQUIFER
WATER TABLE ELEVATION CONTOURS
(4/5/94)
Waukegan Manufactured Gas & Coke Plant

Appendix 5-B

Hydrogeologic Evaluation of Computed Infiltration Rates

APPENDIX 5-B

HYDROGEOLOGIC EVALUATION OF COMPUTED INFILTRATION RATES

Computed aquifer infiltration rates for the WCP site (Section 5.2.1.5) were evaluated relative to observed groundwater elevations using a one-dimensional equation for groundwater elevations in a bounded aquifer receiving uniform infiltration. The equation (Wang and Anderson, 1982) is as follows:

$$h(x) = \frac{R}{(2T)} \left(l^2 - x^2\right)$$

where:

- h = Groundwater elevation in feet (relative to the bounding surface water elevation at each end of the modeled aquifer section)
- x = Distance in feet from the center of the modeled aquifer section
- R = Infiltration rate in feet/day
- T = Aquifer transmissivity in feet^2/day (i.e., hydraulic conductivity times aquifer thickness)
- l = Distance in feet from the center of the modeled aquifer section to the bounding surface water bodies

The height of the groundwater divide midway across the peninsula and south of Slip No. 4 was computed based on the following parameter values:

- x = 0
- R = 11 to 15 inches/year = 2.5×10^{-3} to 3.4×10^{-3} feet/day
- T = (30 feet/day) (25 feet) = 750 feet^2/Day
- l = 900 feet

The computed range of groundwater divide elevations corresponding to the estimated range of infiltration rates is 1.4 to 1.8 feet above the lake level. The median value of observed groundwater divide elevations (relative to lake level) is approximately 1.7 feet (Appendix 5-A). The range of infiltration rates computed from hydrologic data for nearby watersheds is therefore consistent with the observed site groundwater elevation data and measured hydrogeologic parameters.

Appendix 5-C

Groundwater Flow Modeling

APPENDIX 5-C
GROUNDWATER FLOW MODELING

INTRODUCTION

A SLAEM (Single Layer Analytic Element) groundwater model was developed for the Waukegan Manufactured Gas and Coke Plant site (Figure 5-C-1). The model was developed to: (1) provide a tool for integrating and evaluating independent estimates of hydraulic parameters such as hydraulic conductivity and aquifer recharge; and (2) provide a basis for future evaluations of potential groundwater remediation scenarios involving hydraulic controls such as groundwater extraction wells and/or hydraulic barriers. The modeling was also performed to supplement the extensive amount of measured site data for evaluating volumetric discharges of groundwater to Waukegan Harbor and Lake Michigan and to provide a basis for estimating groundwater flow patterns that existed prior to construction of Slip No. 4.

The following sections of this appendix describe the development, calibration, and sensitivity of the SLAEM groundwater model, present simulations and results computed from the groundwater model, and summarize and discuss the groundwater flow modeling.

DEVELOPMENT OF SLAEM GROUNDWATER MODEL

The modeling technique used for this study was the Analytic Element Method (AEM) developed by Dr. Otto D.L. Strack, Professor of Civil Engineering at the University of Minnesota. The theory of the AEM is presented in the textbook *Groundwater Mechanics* (Strack, 1989). This method is incorporated in the SLAEM computer program. A description of the SLAEM computer program is provided in Attachment 5-C-1. As described in Section 5.2.2 of this report, this computer program provides a practical and reliable method for evaluating the hydrogeologic setting of the site.

The SLAEM groundwater model was developed in several steps:

1. Existing geologic and hydrogeologic data were compiled and a conceptual hydrogeologic model was developed.

2. A groundwater flow model was developed for steady-state groundwater conditions at the site. The model was calibrated to time-averaged piezometric conditions for the period from September 29, 1993 to February 3, 1993.

3. The model was modified in order to simulate conditions prior to construction of the new slip. This involved adjusting model elements that define the harbor and adjusting areal infiltration patterns.

Conceptual Hydrogeologic Model

A conceptual hydrogeologic model is important to the development of the SLAEM model because it dictates the level of complexity, appropriate assumptions, and areal extent of the model detail. A SLAEM model is a mathematical representation of the conceptual model. The conceptual model in the vicinity of the site is based on site-specific data and hydrogeologic judgement.

The following summarizes the conceptual hydrogeologic model of the site:

- The aquifer of interest consists of those saturated sediments that overlie a relatively impermeable till unit. These sediments are classified as well-sorted fine to very fine sands with silt contents varying from about 5 to 15 percent. The aquifer is considered an unconfined, homogenous, isotropic unit.

- The areal extent of the modeled aquifer is defined by Lake Michigan to the east, Waukegan Harbor to the south and west, and the North Ditch to the far north. Lake Michigan is in direct connection with the aquifer. Waukegan Harbor is in indirect connection to the aquifer through retaining walls (sheet pile) that define the limits of the harbor. The North Ditch defines a hydraulic boundary to the far north.

- Based on geologic data (Section 5.1), the base elevation of the aquifer ranges from 551 feet MSL near Lake Michigan to 563 feet MSL near containment cell 1 (located west of the North Ditch). Typical base elevations at the site range from 554 feet MSL to 560 feet MSL. Aquifer saturated thicknesses at the site is generally on the order of 25 feet, with local variations (of up to about 4 feet) due to the till surface irregularity and temporal variations (of up to about 3 feet) due to water table fluctuations.

Modeling Assumptions

The model development incorporated the large volume of site-specific geologic and hydrogeologic data collected during the RI (Section 5.0). In addition to the site-specific data, assumptions are necessarily incorporated in the development of a groundwater flow model. Some of the assumptions are inherent in the modeling method and some are necessary to reduce complexity to approximate quantities and parameters involved in the conceptual model. The following assumptions were used in developing the model for the WCP site:

- The modeled aquifer is a single layer system. Interaction with the underlying till unit is considered negligible. This assumption is based on RI data which indicate that the till unit consists of 80 feet of lean clay with some sand and gravel, with laboratory (vertical) hydraulic conductivity values on the order of five orders of magnitude lower than values for the overlying sand unit (Table 4.2-6).

- The aquifer is of infinite areal extent. This assumption is inherent in the SLAEM model. Although the model characterizes Lake Michigan and Waukegan Harbor as aquifer boundaries and the North Ditch as a localized hydraulic boundary, the SLAEM model solves for piezometric conditions beyond these boundaries. This is not considered a limiting assumption but rather allows more accurate simulation of groundwater flow conditions within the aquifer. This in no way affects the accuracy, precision, or reliability of the model solution within the aquifer at the site.

- The Dupuit-Forchheimer Assumption is valid. The Dupuit-Forchheimer Assumption states that resistance to vertical groundwater flow is negligible and that the piezometric level is uniform with depth in the aquifer. The Dupuit-Forchheimer Assumption is not valid where strong vertical gradients exist within the aquifer. This assumption is rarely limiting and is deemed appropriate for this study. This assumption is further supported by water level measurements from nested monitoring wells at the site. These water level measurements show that head differences between the top and bottom of the aquifer were very small to negligible. It should be noted that the Dupuit-Forchheimer Assumption does not necessarily prevent the occurrence of a vertical component of flow.

- Time-averaged groundwater flow can be accurately approximated under steady-state conditions. This assumption is deemed valid for the purpose stated in the prior discussion on the uses for and application of the model for the WCP site (also see Section 5.2.2). This assumption is not considered a limitation because long-term trends of the groundwater flow can be fully characterized.

- The aquifer is isotropic. This assumption is inherent in the SLAEM model. Although vertical anisotropy in hydraulic conductivity was defined in analysis of the pumping test analysis conducted at the site, uncertainties associated with this assumption become associated with the model parameters such as infiltration rate and hydraulic conductivity. The sensitivity of this error to the model becomes negligible when considering the rather broad acceptable range for hydraulic conductivity values and anticipated range of infiltration rates for the site. No indication of horizontal anisotropy was identified from the RI data. The validity of the assumption of isotropy for modeling purposes can be deemed valid.

- The aquifer is separated from Waukegan Harbor by a leaky retaining wall. The retaining wall fully penetrates the aquifer with depth to the till. This assumption is deemed valid, based on available data for harbor wall construction.

- The effective porosity is 38 percent. This is supported from laboratory and grain-size analyses conducted on aquifer samples. This value is also representative of porosities cited by Freeze and Cherry (1979) for similar types of aquifers.

SLAEM Model Elements

The model elements used for the groundwater simulation of the aquifer are the AQUIFER, LINESINK, CUREL, and AREL modules of the SLAEM computer program. The AQUIFER module specifies the global aquifer parameters (i.e., hydraulic conductivity, aquifer base elevation, aquifer thickness, porosity, and specific storage). The LINESINK module specifies lakes and creeks and the CUREL module specifies various curvilinear boundary conditions, such as varying (or constant) piezometric head, constant stream function (i.e., impermeable boundary), or varying (or constant) leaky-resistance conditions. The AREL module specifies the infiltration due to rainfall and recharge due to ponds. The model also requires a reference water elevation at specified coordinates to establish far-field groundwater flow conditions.

The level of detail and types of elements necessary to simulate groundwater flow in the vicinity of the site were determined from the conceptual hydrogeologic model which is based on site-specific hydrogeologic information.

Lake Michigan

Lake Michigan was modeled using a series of head-specified constant-strength linesinks. To specify the heads, the water elevation for Lake Michigan was assigned based on staff gauge data. Constant-strength refers to the behavior of the element discharge along the element. For strings of elements where piezometric head is essentially constant, constant-head linesinks are appropriate. Figure 5-C-2 shows the layout of SLAEM linesink elements used to simulate the piezometric conditions along the shore of Lake Michigan. The SLAEM data files for these LINESINK elements are included in Attachment 5-C-2.

North Ditch and Surface Water Drainage

The North Ditch and the surface water drainage northeast of the site were modeled using a series of head-specified linear-strength linesinks. To specify the heads, water elevations in the ditch and the drainage were obtained from staff gauge data. Linear-strength refers to the behavior of the discharge along the string of elements. Linear-strength linesink elements generally provide a more accurate solution than constant head specifications because the discharge varies linearly along the length of the element. For features where the head varies from element to element (i.e., the North Ditch or the drainage) a gradual change in discharge is modeled. Three head-specified constant-strength linesinks were used to model a ponding area that is located directly east of a storm sewer outlet at the western end of the surface water drainage. Figure 5-C-2 shows the layout of SLAEM head-specified linear-strength linesink elements used to simulate the North Ditch and the head-specified constant-strength and linear-strength linesink elements used to simulate the surface water drainage. The SLAEM data file for these LINESINK elements is included in Attachment 5-C-2.

Waukegan Harbor

The Waukegan Harbor was modeled using the head-specified curvilinear element. The shape of the element is a continuously smooth curve that closely follows the perimeter of the harbor and new slip. The head along this element corresponds to the water elevation in the harbor. The assigned harbor water elevation was determined from staff gauge data. Figure 7-C-3 shows the layout of the SLAEM head-specified curvilinear element used to simulate the water elevation of the Waukegan Harbor. The SLAEM data file for this CUREL element is included in Attachment 5-C-2.

Leaky Retaining Structures Along Waukegan Harbor Perimeter

The leakage from the aquifer into Waukegan Harbor was modeled using the leaky curvilinear element. This element lies between the aquifer and the head-specified curvilinear element. The shape of this element resembles that of the head-specified curvilinear element. The distance between the leaky and head-specified curvilinear element is relatively small compared to the scale of the site so as to simulate the leaky resistance conditions along the western and southern extends of the aquifer. The leaky curvilinear element simulates leakage through the harbor walls and the slurry wall that separates the aquifer from the harbor. The direction of leakage is governed by the direction of high piezometric head to low piezometric head. The magnitude of the leakage is controlled along the curvilinear element by specifying resistances, where the resistance is defined as the ratio of thickness to permeability.

Data for resistance are available for a portion of the element that represents the slurry wall on the eastern section of Slip No. 4. Here, the thickness of the slurry wall is 2 feet with a design permeability requirement of 10^{-7} cm/sec (2.8×10^{-4} ft/day; Canonie, 1991). Therefore, the resistivity along the slurry wall is 7,100 days, using the ratio of thickness to permeability. The resistances along the remaining portions of the leaky curvilinear element were determined through the calibration process. Figure 5-C-3 shows the layout of the SLAEM leaky curvilinear element used to simulate the leakage of groundwater from the site to Waukegan Harbor and Slip No. 4. The SLAEM data file for this CUREL element is included in Attachment 5-C-2.

Containment Cells and Building Foundation

Three containment cells have been constructed in the vicinity of the WCP site. Two containment cells, cell 1 and cell 2, are located near the north ditch. The third containment cell is located at the former Slip No. 3.

The foundation of the eastern-most building of the OMC Plant No.2 reportedly extends to the till. It is assumed that the foundation acts as a hydraulic barrier such that groundwater is prevented from flowing within the confines of the foundation.

All of these areas (containment cells and foundation) represent areas of no flow in the aquifer and were modeled using impermeable curvilinear elements. The impermeable curvilinear element simulates an impermeable boundary condition along the element. By linking these elements into a closed shape (i.e., containment cell or foundation), the inside of the this shape becomes a no flow region of the aquifer and the groundwater flows around these closed shapes. Figure 5-C-4 shows the layout of SLAEM impermeable curvilinear elements used to simulate the containment cells and foundation. The SLAEM data file for these CUREL elements are included in Attachment 5-C-2.

Infiltration

Infiltration due to direct precipitation was modeled using given-strength areal elements. Areal elements are quadrilateral features that can be positioned on the top or bottom of an aquifer to simulated recharge or discharge. Given-strength refers to the rate at which recharge or discharge is applied to those elements. The given-strength areal elements that were used to simulate infiltration at the site simulate recharge to the top of the aquifer. Areas in the vicinity of the site (including the site) were designated as either infiltrating or noninfiltrating areas. Noninfiltrating areas are those areas where infiltration is inhibited because pavement, buildings, or containment cells cover that area. The areas designated as infiltrating areas were divided into quadrilateral areas, therefore defining a mesh of areal elements. Figure 5-C-5 shows the layout of the mesh of SLAEM given-strength areal elements used to simulate infiltration to the aquifer due to direct rainfall. The SLAEM data file for these AREL elements is included in Attachment 5-C-2.

Monitoring Wells

The site monitoring well network was included in the model using a map file to define well positions. Figure 5-C-6 shows the layout of the monitoring well network. The SLAEM map file for these monitoring well locations is included in Attachment 5-C-2.

Summary of SLAEM Elements

Figure 5-C-7 illustrates the conceptual layout of all SLAEM elements used to simulate hydrogeologic features at the site.

Model Calibration

The model was calibrated to steady-state conditions that simulate a long-term trending average in piezometric conditions. Simulated groundwater elevations were compared to observed piezometric heads for a six-month period (September 1993 - February 1994). A plot of time-averaged piezometric heads at each measuring location was used as a guide for calibration. Figure 5-C-8 illustrates contours of average observed piezometric head during the six-month period. Model results were also compared to individual data sets for piezometric head measurement events (Appendix 5-A) to provide a steady-state simulation representative of observed site gradients and flow patterns.

The aquifer hydraulic conductivity, infiltration rate of areal elements, and (to a lesser degree) the resistance values along the leaky curvilinear element were adjusted to obtain a reasonable fit for the representation of average piezometric levels shown on Figure 5-C-8. Table 5-C-1 summarizes the parameter values of the SLAEM elements that were obtained through final calibration of the model. The resulting value for hydraulic conductivity is within the expected range of values observed from analyses of slug tests and pumping tests conducted at the site (Section 5.2.1.2). The resulting value of infiltration rate is within the expected range of values determined from hydrogeologic data (Section 5.2.1.4).

Figure 5-C-9 shows contours of computed piezometric head from the calibrated model. Table 5-C-2 provides a comparison of simulated head with the average observed head for each monitoring well. The maximum difference occurs at P-105 and MW-12S with -0.40 and 0.45 feet, respectively. The average of the absolute value of difference between the simulated and average observed head is 0.17, with a standard deviation of 0.14.

The distribution of error indicates two areas in which higher differences between predicted and observed heads are concentrated. One area is located in the vicinity of Wells MW-12S, MW-13S, MW-8S, and P-105. The other is located in the vicinity of Wells MW-11S, MW-15S, and MW-3S. These concentrations in error indicate that there are likely spatial variations in hydraulic conductivity and infiltration in these areas that are not accounted for by the model assumptions of constant hydraulic conductivity and infiltration. Efforts to define detailed and specific spatial variations of hydraulic conductivity and/or infiltration in these areas are not warranted, because the error differences do not compromise the ability of the model to either (1) provide information for evaluating overall site hydrogeologic characteristics; or (2) provide a basis for future evaluations of significant stresses on the groundwater flow system (e.g., potential extraction wells and/or hydraulic barriers).

The simulation results show that site groundwater flows primarily toward the harbor, with groundwater in the eastern-most portion of the site flowing toward Lake Michigan. This pattern is consistent with observed groundwater flow patterns (Appendix 5-A).

The simulated groundwater divide is located in the vicinity of Wells MW-4S, MW-7S, and MW-9S. This position is consistent with the groundwater divide shown by observed groundwater flow patterns (Appendix 5-A).

The simulated groundwater contours in Figure 5-C-9 indicate that flow is toward the slip in the northern portion of the site directly north of the slip. The source of flow is principally from infiltration north of the site. This portion of the simulation corresponds well with time averaged observations of head in the vicinity north of the slip that are presented in Figure 5-C-8.

In the vicinity of the site directly south of the eastern most building of OMC Plant No.2, groundwater flow is generally in a southwestern, southern, and southeastern direction. These predicted flow directions correspond well with flow directions indicated by the time-averaged observations of head presented in Figure 5-C-8. The small hydraulic gradients directly south of the eastern most building are most likely the result of the restriction of flow from north of the site due to the foundation of the eastern most building acting as a hydraulic barrier (i.e., no flow region in the aquifer). Given that: (1) the area defined by Monitoring Wells MW-11S, MW-3S, P-102, MW-14S, and Segments A-B, B-C, C-D, D-E, E-F, F-G, and G-H (Figure 5-C-14) is approximately 1,745,000 square feet in size; (2) the infiltration rate is 0.0031 feet/day, and (3) the sum of computed discharges at Segments A-B, B-C, C-D, D-E, E-F, F-G, and G-H is approximately 6,200 ft^3/day (Table 5-C-4), it is estimated that a groundwater flux of approximately 800 ft^3/day enters the site at the northern boundary of the site. Of this amount, approximately 740 ft^3/day enters the site between Wells MW-11S and MW-3S from west of the easternmost building and discharges entirely to Slip No. 4 along Segment A-B (Figure 5-C-14). Approximately 60 ft^3/day, which represents less than one percent of the total discharge through Segments A-B through G-H, enters the site south of the easternmost building. This mass balance calculation indicates that the gradient that is exhibited south of the eastern-most building is principally generated from local infiltration in that vicinity and does not represent significant flow entering the site from beneath OMC Plant No. 2.

Simulated hydraulic gradients toward the harbor, and toward Lake Michigan, and toward the south are 0.0019, 0.0025, and 0.0007, respectively. These values represent good matches for average hydraulic gradient values (0.0021 toward the harbor, 0.0026 toward Lake Michigan, and 0.0006 toward the south) computed from the observed groundwater flow patterns (Appendix 5-A).

Simulated groundwater elevations at the on-site groundwater divide (east of Slip No. 4) are on the order of 582.75 feet MSL. This value is representative of overall observed conditions for the period from September 1993 through February 1994 (Appendix 5-A), since it is about midway between the highest observed value for this period (approximately 583.4 feet MSL, September 1993) and the lowest observed value for this period (approximately 582.2 feet MSL, February 1994).

Sensitivity Analysis of the SLAEM Model

During the calibration process, it was observed that the groundwater flow system at the site is heavily influenced by the interaction between infiltration and hydraulic conductivity. To a lesser extent, the flow system may be influenced by the rate of leakage through the sheet pile walls of the harbor and the sheet pile and slurry walls of Slip No. 4. It was deemed important to perform a sensitivity analysis of these model parameters in order to quantify their importance in governing the groundwater flow system.

The SLAEM model was analyzed to assess its sensitivity to three hydrogeologic characteristics. The three hydrogeologic characteristics analyzed for sensitivity are:

- Infiltration.
- Hydraulic conductivity.
- Leakage of groundwater through the retaining structures that separate the harbor and slip from the aquifer.

The sensitivity analysis was performed by systematically changing calibrated values of these characteristics. Since the groundwater flow system at the site is defined mainly by the interaction between infiltration and hydraulic conductivity, both of which are well documented for the site, model sensitivities to these parameters were examined only over ranges of values that produced reasonable groundwater flow results. If, for example, the overall model hydraulic conductivity had been varied over the entire range of values otherwise developed during the RI, the extreme values would have corresponded to infiltration rates significantly outside the range of infiltration rates established for the site.

The sensitivity analysis was performed by changing one parameter value at a time. The resulting hydraulic heads in the aquifer were compared to those computed by the calibrated model. Comparisons were made at easily referenced locations across the site -- Monitoring Wells MW-1S, MW-3S through MW-15S, P-102 through P-105, and P-107. These locations provide representative areal coverage of the site. Variations of piezometric heads at the locations of these wells are, therefore, representative of the effects of the varied parameters on piezometric heads in the aquifer.

The magnitude of change in heads from the calibrated solution was used as a measure of the sensitivity of the model solution to a particular parameter (Anderson and Woessner, 1992). These changes in heads were characterized by two statistical parameters:

- The average difference between the simulated piezometric heads for the calibrated model and the test model (model in which the parameter was varied) at the selected wells.

- The standard deviation of these differences.

The first parameter is a measure of the overall deviation from the piezometric heads computed across the site. The second parameter is a measure of the difference of these variations across the site. The smaller the standard deviation, the more uniform the deviations from the calibrated heads across the site are.

The following sections describe the procedure and the results of the sensitivity analysis to each of the parameters varied.

Sensitivity to Infiltration Rate

Infiltration was modeled as areal elements with specified infiltration rates. Model sensitivity to this parameter was analyzed by determining the effects of decreasing and increasing these rates by 25 percent.

The average difference between the simulated hydraulic heads for the calibrated model and the test model, and the standard deviation of these differences were computed to be -0.30 feet and 0.08 feet, respectively, for the case in which the infiltration rates were reduced by 25 percent, and 0.22 feet and 0.06 feet, respectively, for the case in which the infiltration rates were increased by 25 percent (Table 5-C-3).

Sensitivity to Hydraulic Conductivity

Model sensitivity to this parameter was analyzed by determining the effects of decreasing and increasing these rates by 25 percent.

The average difference between the simulated hydraulic heads for the calibrated model and the test model, and the standard deviation of these differences were computed to be -0.13 feet and 0.05 feet, respectively, for the case in which the hydraulic conductivity was reduced by 25 percent, and 0.33 feet and 0.13 feet, respectively, for the case in which the hydraulic conductivity was increased by 25 percent (Table 5-C-3).

Sensitivity to Leakage of Groundwater through the Retaining Structures That Separate the Harbor and Slip from the Aquifer

The sensitivity of the SLAEM model was analyzed by varying the prescribed resistances of the curvilinear leaky element. The resistances were decreased and increased by 25 percent.

The average difference between the simulated hydraulic heads for the calibrated model and the test model, and the standard deviation of these differences were computed to be -0.09 feet and 0.05 feet, respectively, for the case in which the resistance values were decreased by 25 percent, and 0.06 feet and 0.03 feet, respectively, for the case in which the resistance values were increased by 25 percent (Table 5-C-3).

Discussion of Sensitivities

The results from the sensitivity analysis, as described above and presented summarily in Table 5-C-3, suggest that the model results are more sensitive to variations in infiltration and hydraulic conductivity than to variations in the flow resistance of the slip/harbor walls. These results indicate that the extensive, site-specific database established for hydraulic conductivity will be an integral component for the development of future simulations of potential groundwater remedial scenarios. Similarly, remedial scenarios that may involve alterations to current patterns of infiltration may have significant effects on groundwater flow that may be examined in groundwater flow simulations.

RESULTS

Results of Simulation of Conditions Prior to Slip No. 4 Construction

A simulation was performed of groundwater conditions during the period prior to construction of Slip No. 4 and after production activity had ceased at the manufactured gas and coke plant (i.e., approximately 1972 to 1992). Elements of the calibrated model were changed to reflect the former configuration of the harbor and Slip No. 3. The containment area that encompassed Slip No. 3 in the calibrated model and the OMC containment cells to the north (see Figure 5-C-4) were removed. The curvilinear leaky and head-specified elements of the calibrated model (see Figure 5-C-3) were replaced by another set of curvilinear leaky and head-specified elements. Figure 5-C-10 illustrates the layout of curvilinear elements used to simulate groundwater leakage to the harbor during the period prior to construction of the new slip.

Figure 5-C-11 illustrates the computed piezometric head contours representative for this period. These contours represent a simulated long-term average of groundwater flow conditions during the period between the end of production at the manufactured gas and coke plant and the construction of the new slip.

Figure 5-C-12 shows the location of a cross-sectional trace used to develop the cross section shown on Figure 5-C-13. The flow path traces on Figure 5-C-13 were generated from the SLAEM simulation of groundwater during this period. The downward component of the flow paths result from natural recharge from precipitation. Each dot along a flow path trace represents a computed flow time of 100 days.

Results of Simulation Including Slip No. 4

Total discharges from the calibrated model were computed along segments indicated on Figure 5-C-14. The total discharge rates along these segments are presented in Table 5-C-4. The computed discharge (along Segments A and E) to the harbor for the simulation incorporating Slip No. 4 is approximately 10 percent greater than the computed discharge for the simulation of conditions prior to Slip No. 4 construction.

SUMMARY

A groundwater model was developed for the WCP site using the SLAEM groundwater flow program. The resulting SLAEM groundwater model is based on existing site-specific geologic and hydrogeologic data. These data were used to develop a conceptual model. From this conceptual model, the specific elements of the SLAEM model were developed. These elements are represented in SLAEM data files (Attachment 5-C-2) as summarized in Table 5-C-1. The calibrated groundwater model is a steady-state simulation of average piezometric conditions for the period from September 1993 to February 1994. The hydraulic conductivity and infiltration parameters of the calibrated model correspond well to expected ranges determined from slug test and pumping tests conducted for hydraulic conductivity analysis and from the hydrologic model used for infiltration estimates.

The calibrated groundwater model was used to simulate piezometric conditions for the period prior to construction of Slip No. 4 and after production activities ceased at the manufactured gas/coking plant. The results of this simulation have been used, where appropriate, to supplement site data in RI evaluations.

Based on observed site groundwater elevations and measured hydrogeologic parameters, the groundwater flow model provides a representative simulation of site hydrogeologic conditions and can be used to assess the effectiveness of potential remedial alternatives involving hydraulic controls (i.e., groundwater extraction and/or hydraulic barriers).

REFERENCES

Anderson, M.P. and W.W. Woessner. 1992. Applied Groundwater Modeling, Simulation of Flow and Advective Transport. Academic Press, Inc., San Diego, California.

Canonie Environmental. 1991. Data Report, Soils and Water Test Results, November 1990 to June 1991, New Slip Area.

Freeze, R.A. and J.A. Cherry. 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliff, New Jersey.

Strack, O.D.L. 1989. Groundwater Mechanics. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

TABLE 5-C-1

SUMMARY OF SLAEM INPUT DATA FOR CALIBRATION

AQUIFER MODULE	
Base Elevation of Aquifer	557 feet, MSL
Thickness of Aquifer	33 feet
Hydraulic Conductivity of Aquifer	31 feet/day
Porosity of Aquifer	0.38
AREAL ELEMENT MODULE	
Infiltration Rate	0.0031 feet/day
LINESINK MODULE (CONSTANT)	
Water Elevation of Lake Michigan	581 feet, MSL
Water Elevation of Ponding Area (East of Storm Sewer Outlet)	582.49 feet, MSL
LINESINK MODULE (LINEAR)	
Water Elevations of North Ditch	582.84 to 581 feet, MSL
Water Elevations of Surface Water Drainage (Northeast of Site)	582.49 to 581 feet, MSL
CURVILINEAR MODULE (HEAD)	
Water Elevation of Waukegan Harbor	581 feet, MSL
CURVILINEAR MODULE (LEAKY)	
Resistance Values of Slurry Wall (Eastern End of Slip No.4)	7,100 days
Thickness of Slurry Wall (Eastern End of Slip No.4)	2 feet
Resistance Values of Retaining Walls Along Harbor	2 to 20 days
Estimated Thickness of Retaining Walls Along Harbor	1 foot

TABLE 5-C-2

CALIBRATION RESULTS FOR SLAEM MODELING

WELL NO.	SIMULATED PIEZOMETRIC HEAD (feet, MSL)	AVERAGE OBSERVED PIEZOMETRIC HEAD (feet, MSL)	DIFFERENCE (feet, MSL)
P-102	582.75	582.62	0.13
P-103	582.31	582.32	-0.01
P-104	582.64	582.60	0.04
P-105	582.06	582.46	-0.40
P-107	582.19	582.20	-0.01
W-2A	582.82	582.83	-0.01
W-4A	582.86	582.82	0.04
W-5	583.04	582.85	0.19
W-6	583.03	582.84	0.19
W-12	582.41	582.74	-0.33
W-13	582.43	582.68	-0.25
MW-1S	582.32	582.37	-0.05
MW-3S	582.86	582.67	0.19
MW-4S	582.41	582.59	-0.18
MW-5S	581.61	581.28	0.33
MW-6S	581.61	581.55	0.06
MW-7S	582.66	582.75	-0.09
MW-8S	581.89	582.14	-0.25
MW-9S	582.53	582.59	-0.06
MW-10S	581.94	581.91	0.03
MW-11S	582.51	582.14	0.37
MW-12S	581.93	582.38	-0.45
MW-13S	582.42	582.76	-0.34
MW-14S	582.47	582.53	-0.06
MW-15S	582.97	582.74	0.23

TABLE [illegible]-C-3

RESULTS OF SENSITIVITY ANALYSIS

HYDROLOGIC CHARACTERISTIC VARIED	PARAMETER VARIED	% CHANGE[a] IN HYDROLOGIC CHARACTERISTIC VARIED	RESULTING CHANGES	
			AVERAGE DIFFERENCE[b] (feet)	STANDARD DEVIATION[c] (feet)
Infiltration	Infiltration Rate	-25	-0.30	0.08
		+25	+0.22	0.06
Hydraulic Conductivity	Hydraulic Conductivity	-25	-0.13	0.05
		+25	+0.33	0.13
Leakage Through Leaky Element Separating the Aquifer from Waukegan Harbor	Resistance of Leaky Element	-25	-0.09	0.05
		+25	+0.06	0.03

[a] Percent changed from calibrated value computed for the hydrologic characteristic varied.

[b] Average difference between simulated piezometric heads for test and for calibrated model.

[c] Standard deviation of the differences between simulated piezometric heads for test and for calibrated model.

TABLE 5-C-4

SUMMARY OF TOTAL DISCHARGE COMPUTED FROM THE CALIBRATED SLAEM MODEL

SEGMENT	COMPUTED SLAEM DISCHARGE (FT^3/DAY)
A-B	1,379
B-C	140
C-D	731
D-E	1,153
E-F	0
F-G	578
G-H	2,262

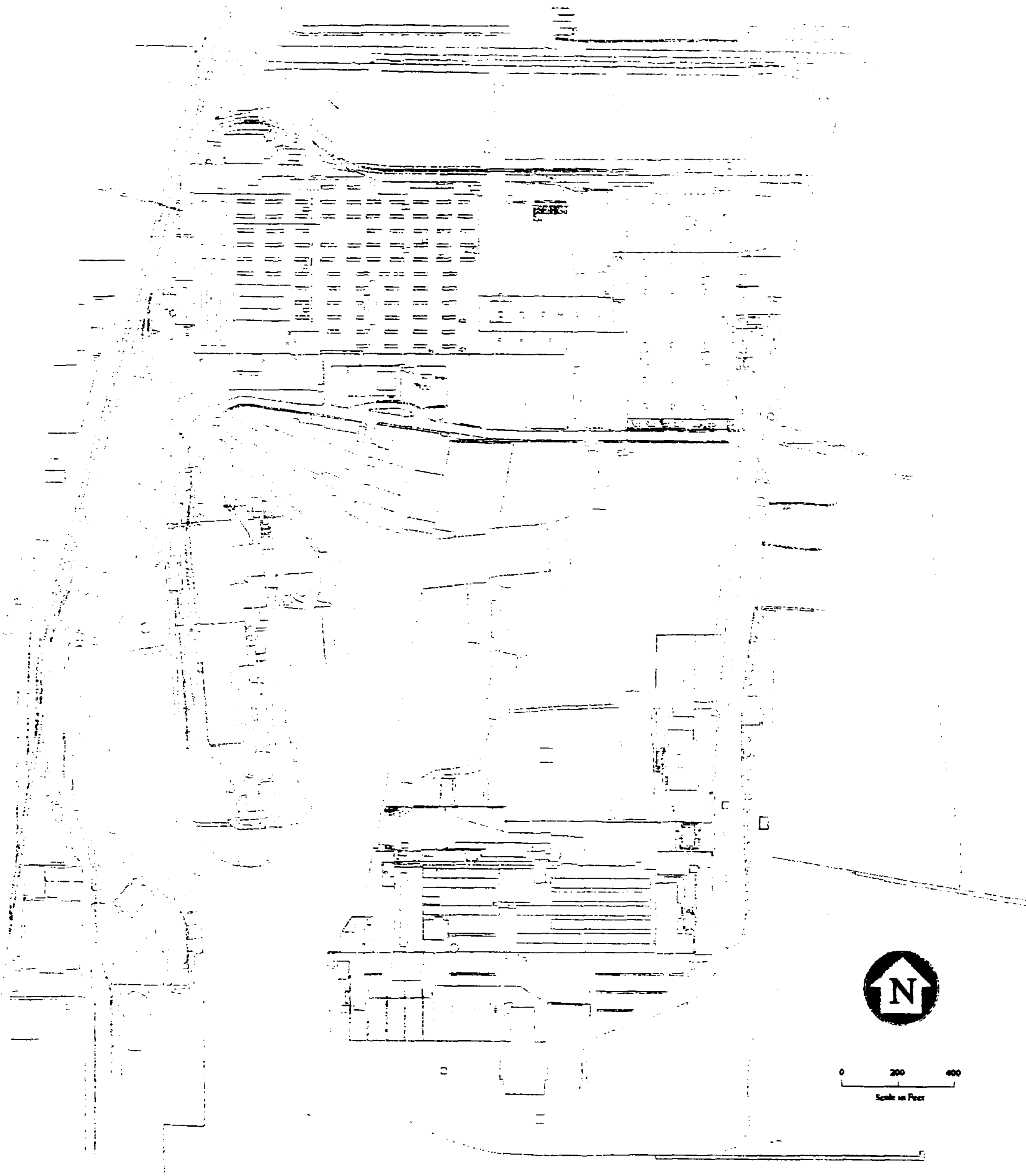


Figure 5–C–1

SITE MAP

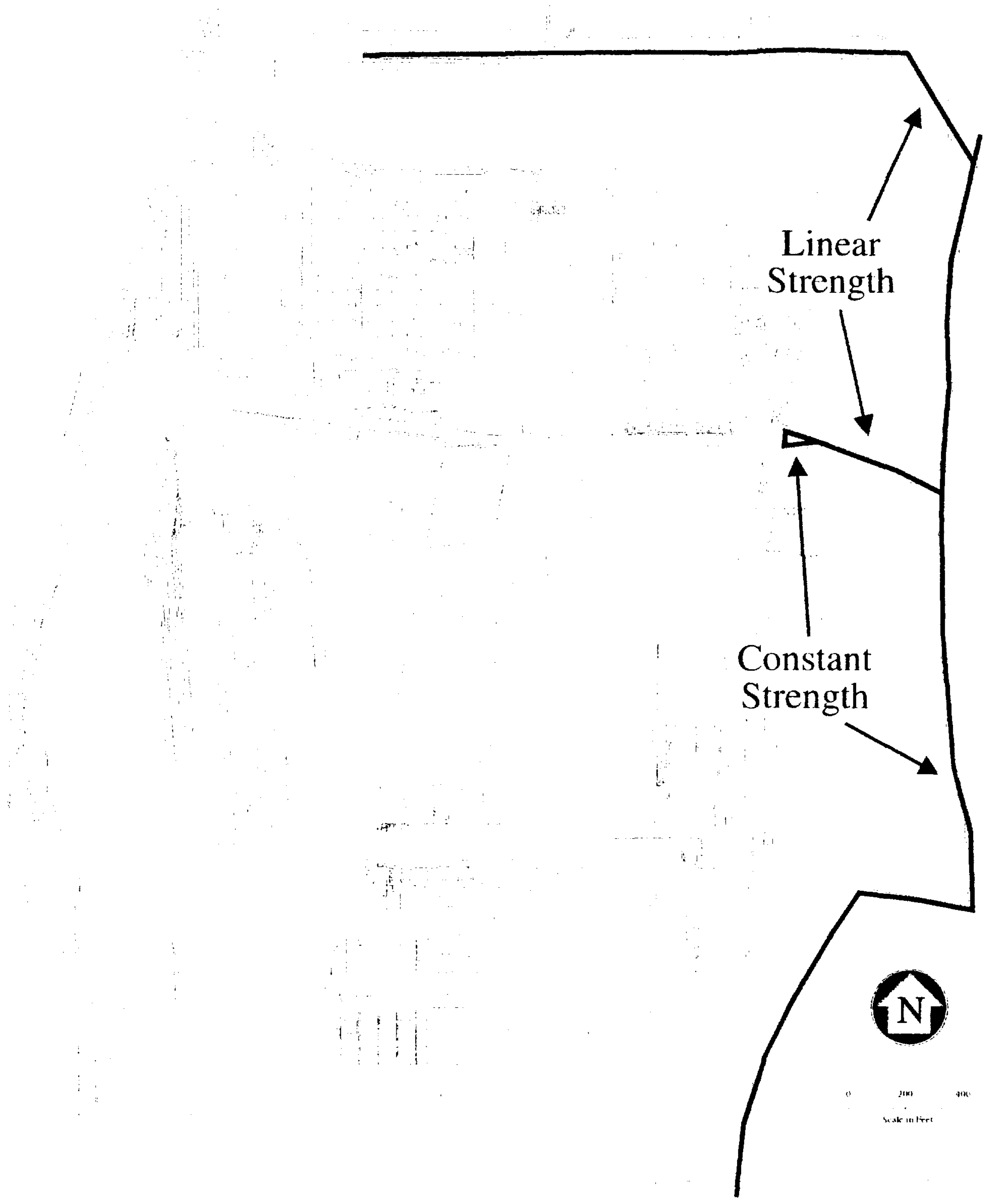


Figure 5–C–2

LAYOUT OF SLAEM LINESINK ELEMENTS
(CONSTANT AND LINEAR STRENGTH)
USED TO SIMULATE LAKE MICHIGAN AND DRAINAGES

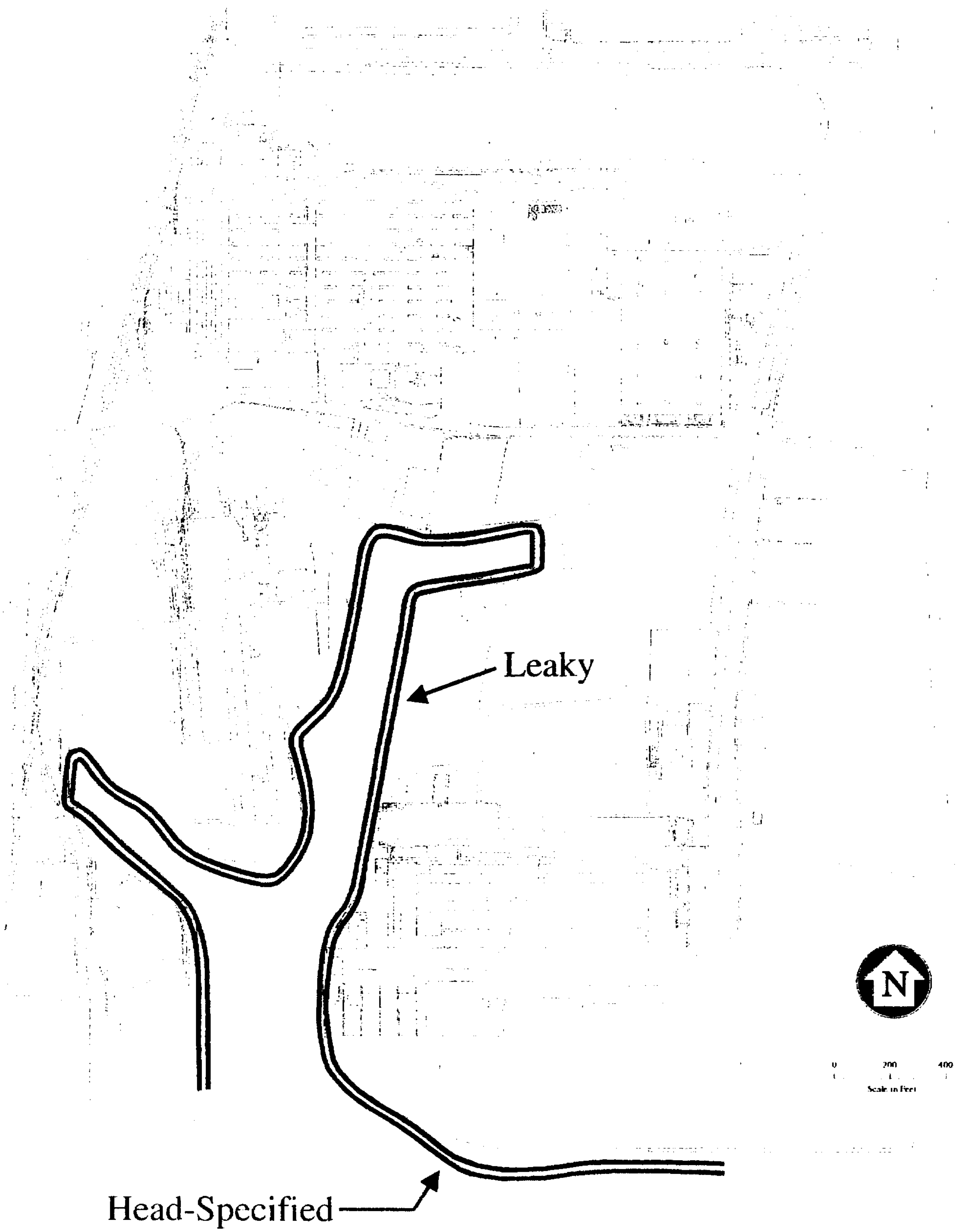


Figure 5-C-3

LAYOUT OF SLAEM CURVILINEAR ELEMENTS
(LEAKY AND HEAD-SPECIFIED)
USED TO SIMULATE GROUDWATER LEAKAGE INTO HARBOR

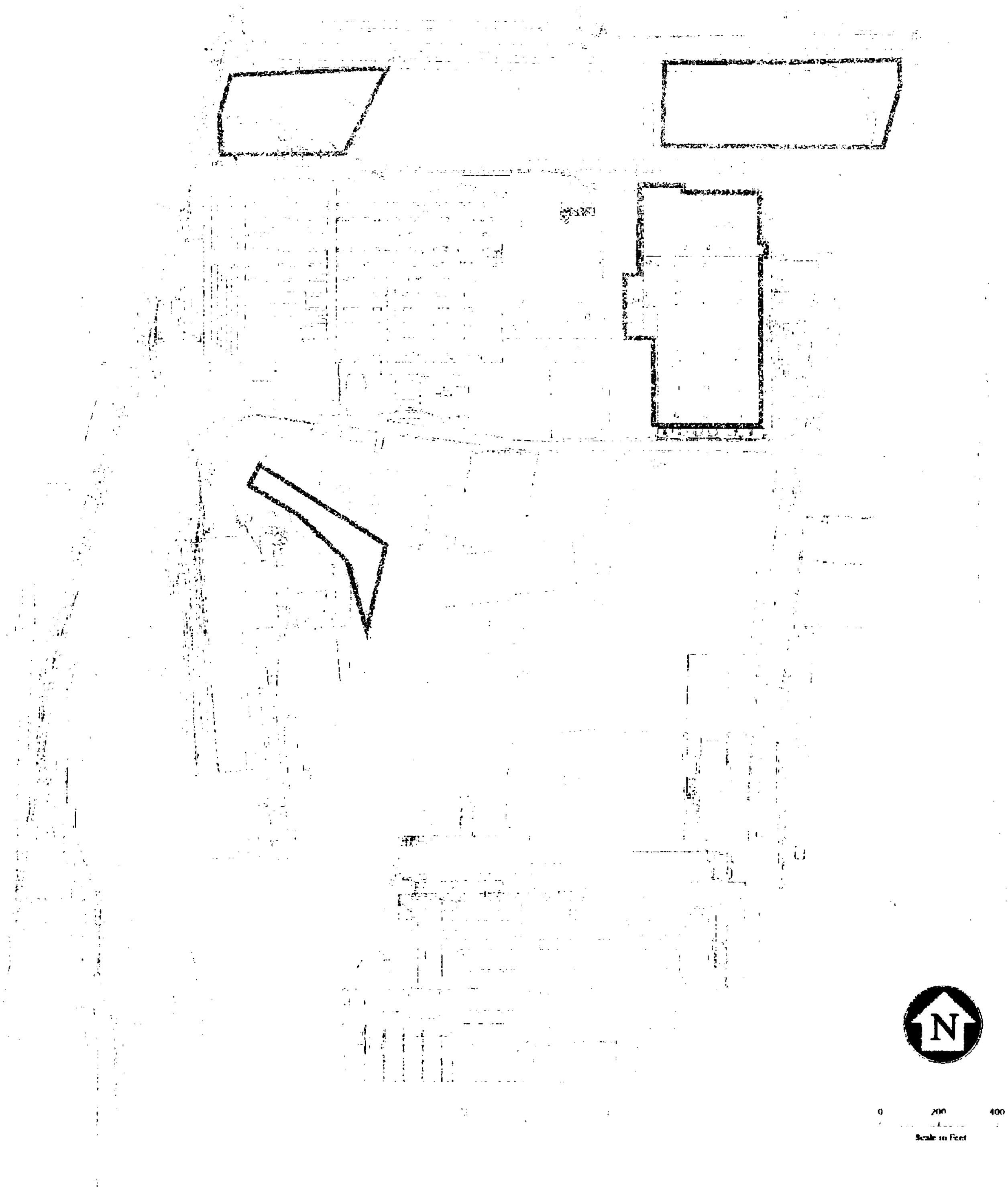


Figure 5-C-4

LAYOUT OF SLAEM CURVILINEAR ELEMENTS
(IMPERMEABLE)
USED TO SIMULATE CONTAINMENT AREAS AND BUILDING FOUNDATIONS

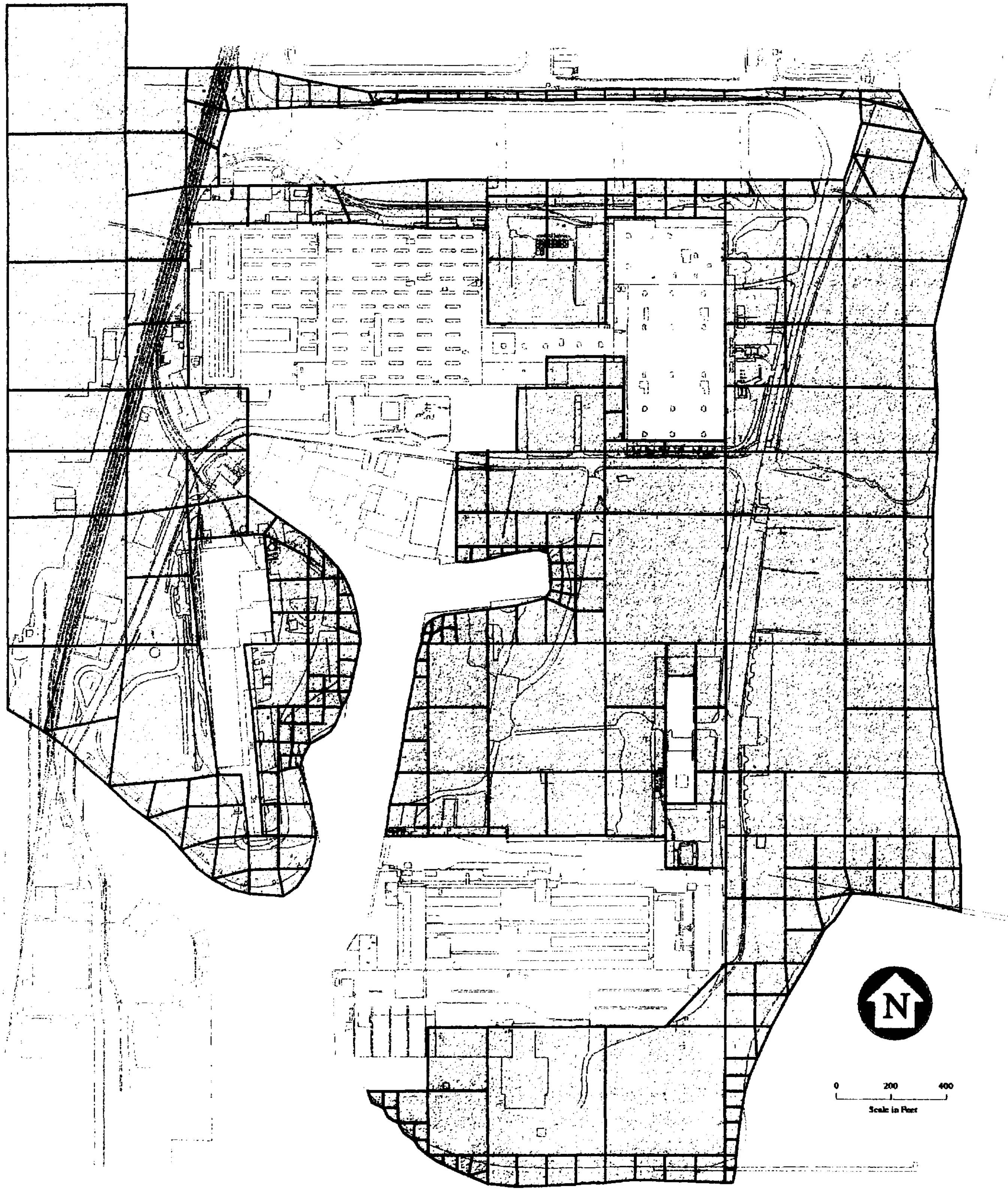


Figure 5-C-5

LAYOUT OF SLAEM AREAL ELEMENTS
(GIVEN STRENGTH)
USED TO SIMULATE AREAS OF INFILTRATION

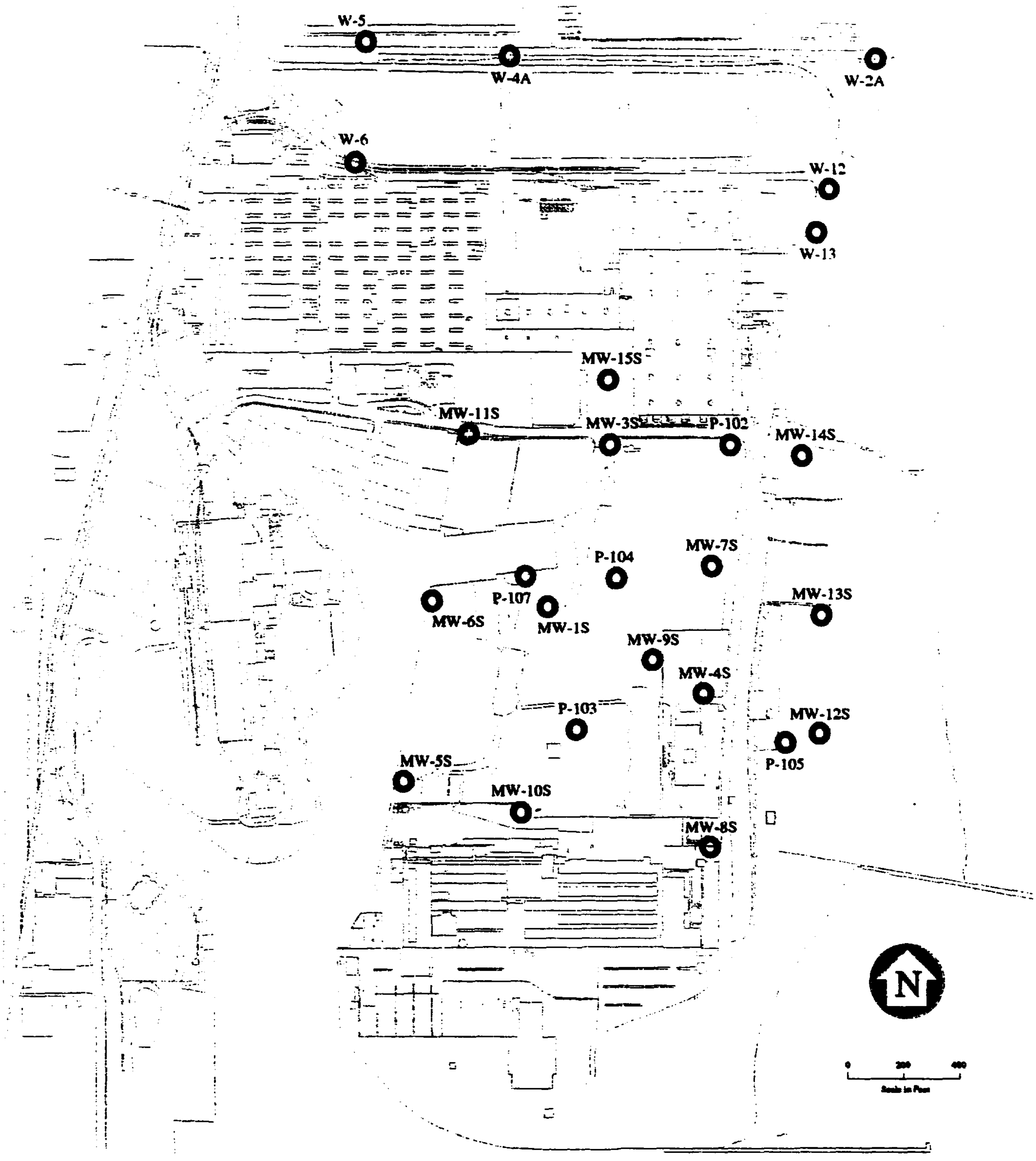


Figure 5-C-6

LAYOUT OF MONITORING WELLS
USED FOR CALIBRATION OF SLAEM MODEL

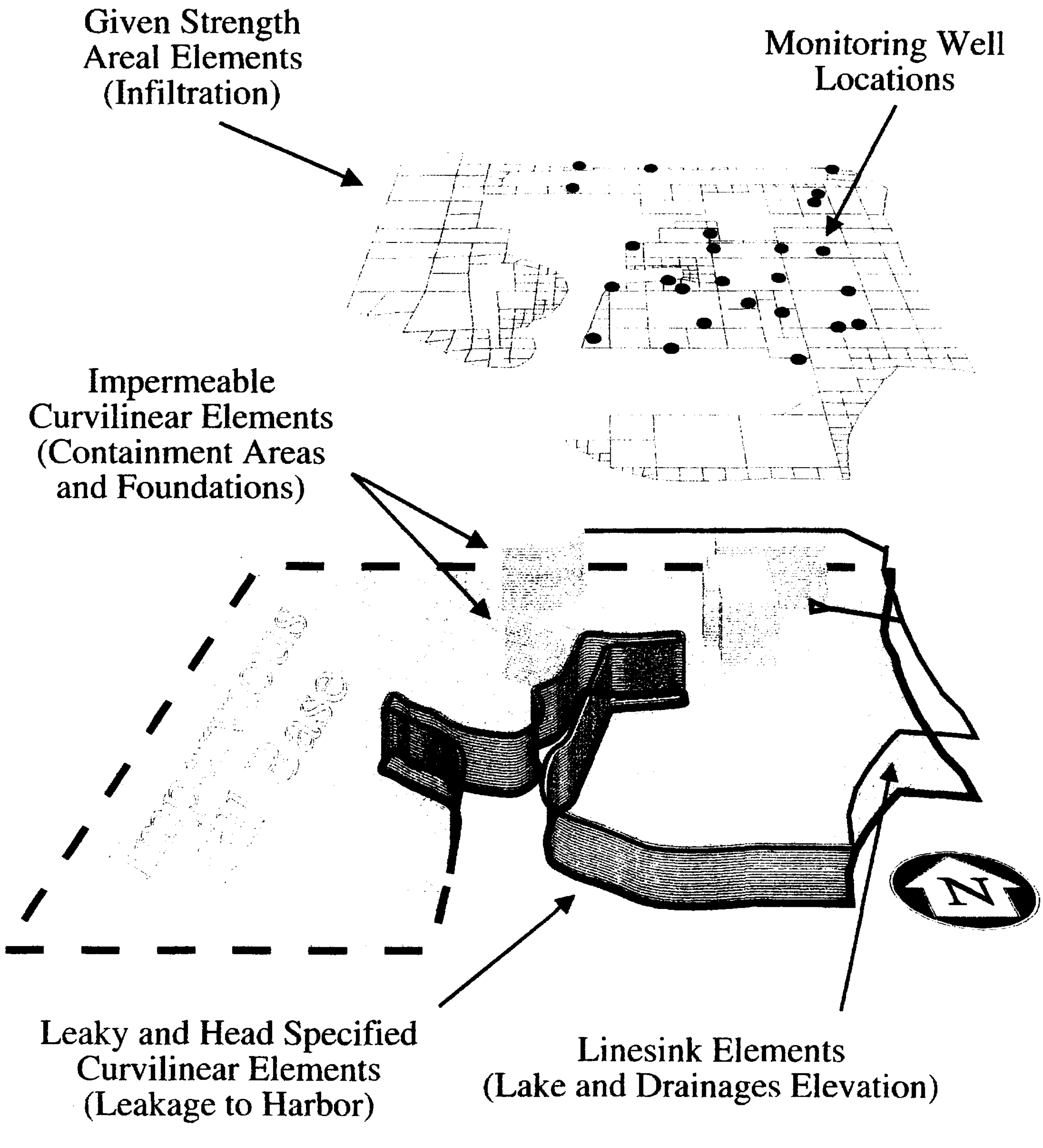


Figure 5-C-7

CONCEPTUAL LAYOUT (PERSPECTIVE VIEW)
OF SLAEM ELEMENTS
USED TO SIMULATE GROUNDWATER FLOW CONDITIONS

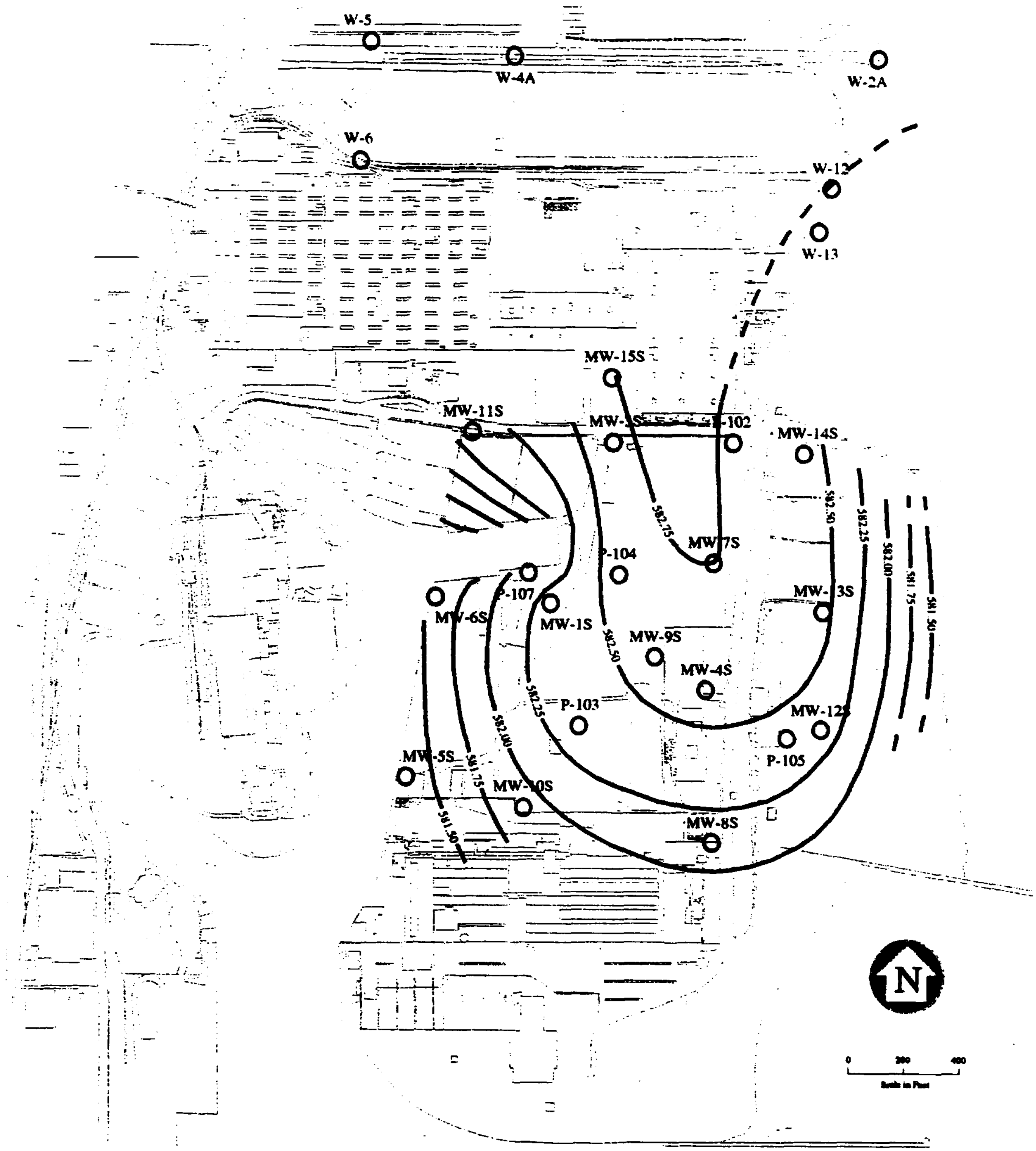


Figure 5-C-8

CONTOURS OF AVERAGE OBSERVED PIEZOMETRIC HEADS
(SEPTEMBER 1993 - FEBRUARY 1994)

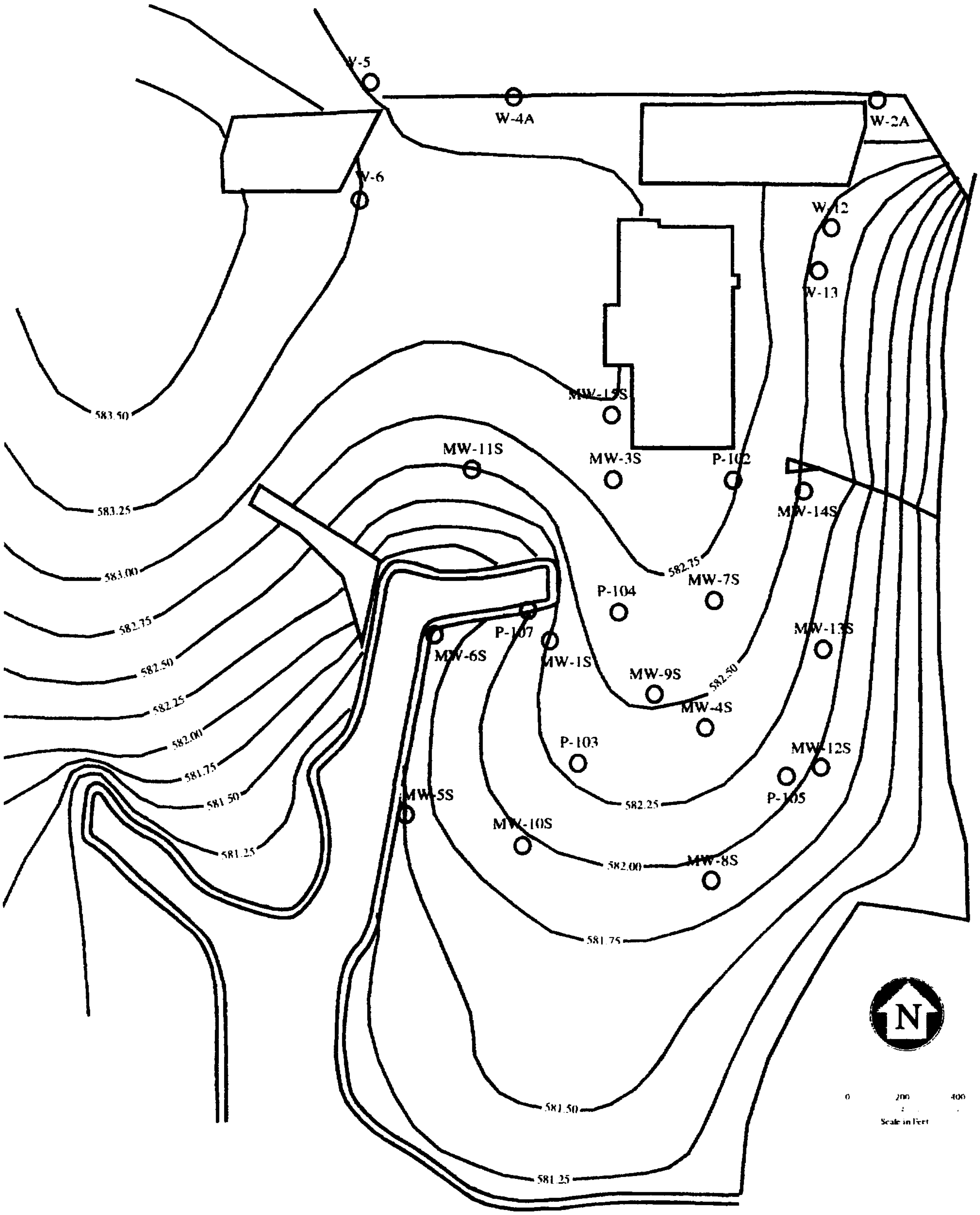


Figure 5-C-9

CONTOURS OF SIMULATED PIEZOMETRIC HEAD
FROM THE SLAEM GROUNDWATER MODEL
(SITE CALIBRATED)

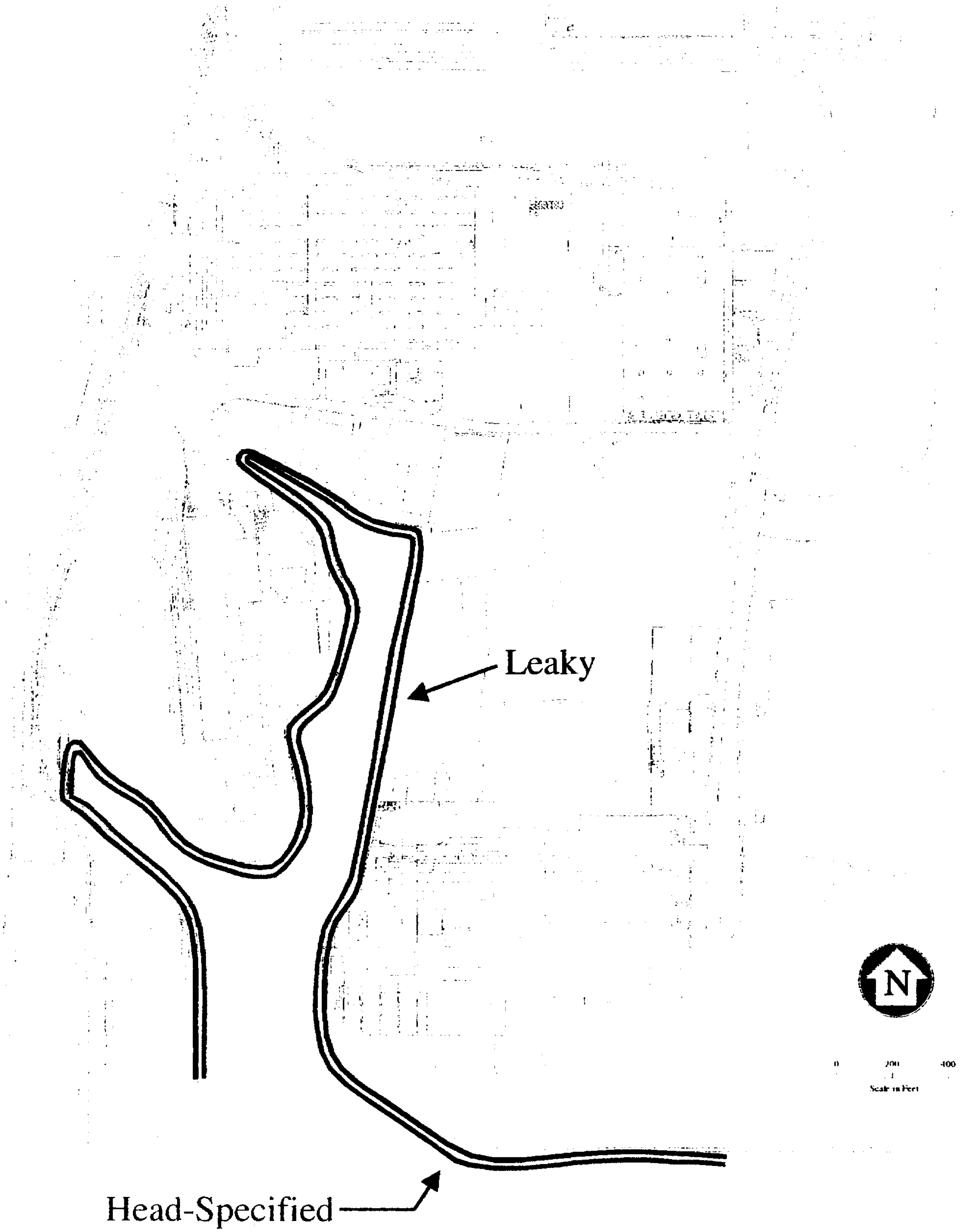


Figure 5-C-10

LAYOUT OF SLAEM CURVILINEAR ELEMENTS
(LEAKY AND HEAD-SPECIFIED)
USED TO SIMULATE GROUDWATER LEAKAGE INTO HARBOR
PRIOR TO CONSTRUCTION OF SLIP NO.4

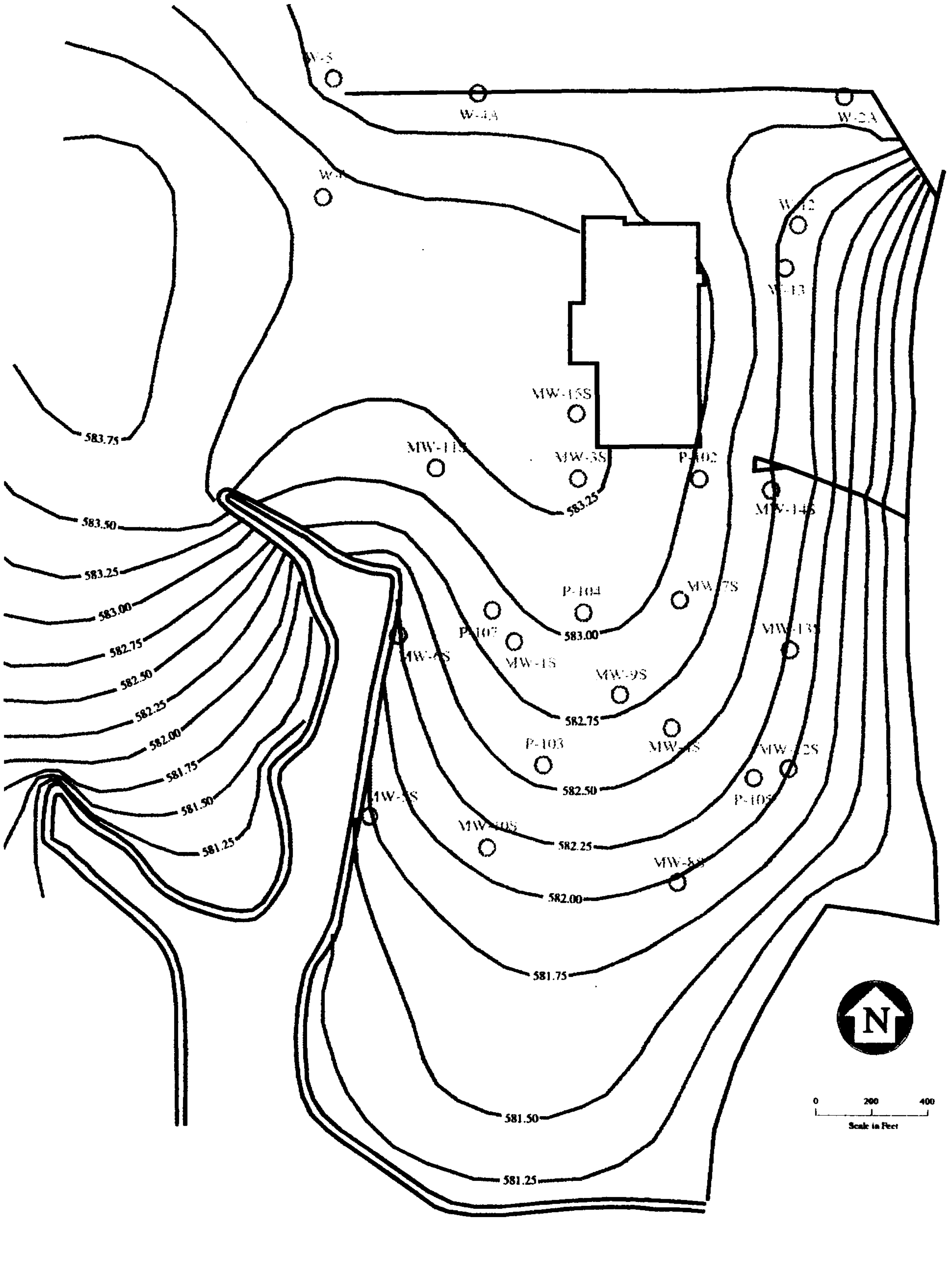


Figure 5-C-11

CONTOURS OF SIMULATED PIEZOMETRIC HEAD
FOR GROUNDWATER CONDITIONS
PRIOR TO CONSTRUCTION OF SLIP NO.4 AND
AFTER PRODUCTION ACTIVITY

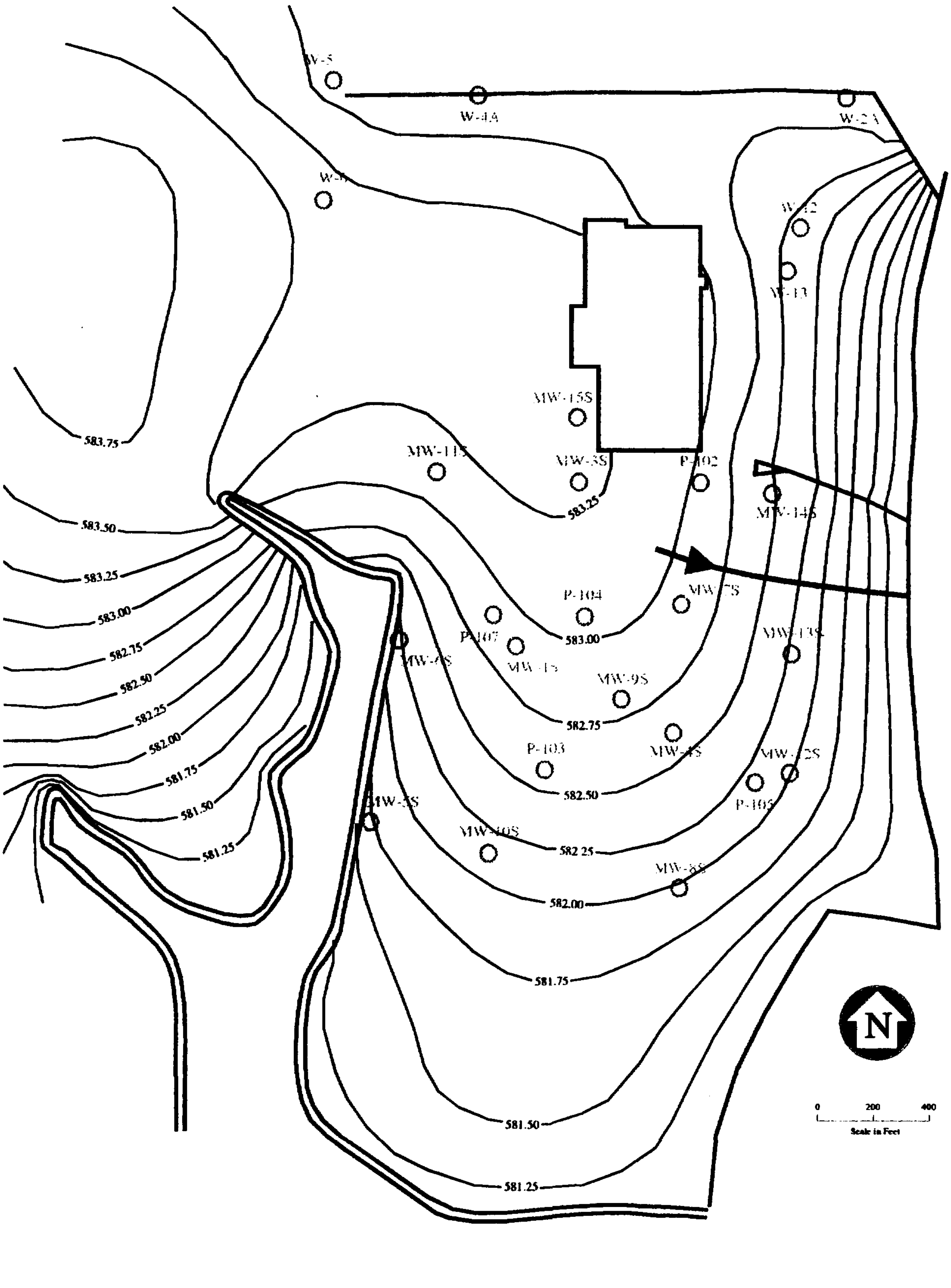
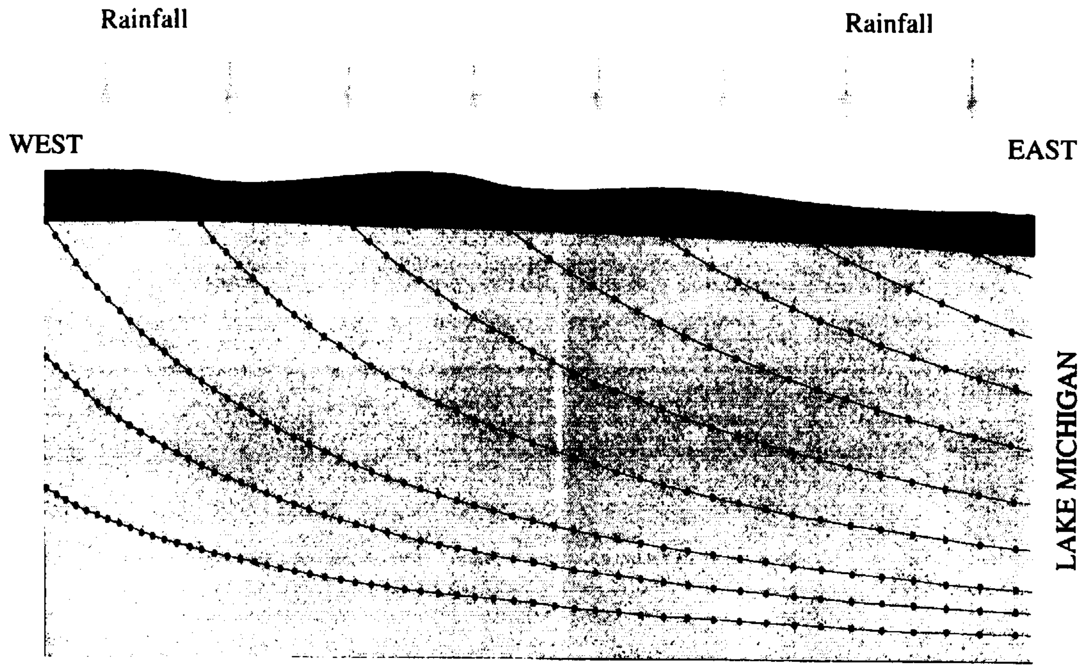


Figure 5-C-12

LOCATION OF CROSS-SECTIONAL TRACE

(PRIOR TO CONSTRUCTION OF SLIP NO.4 AND AFTER PRODUCTION ACTIVITY)



Note: Each dot along a trace represents 100 days.

Vertical Exaggeration: 10X

Figure 5-C-13

CROSS SECTION

(PRIOR TO CONSTRUCTION OF SLIP NO.4
AND AFTER PRODUCTION ACTIVITY)

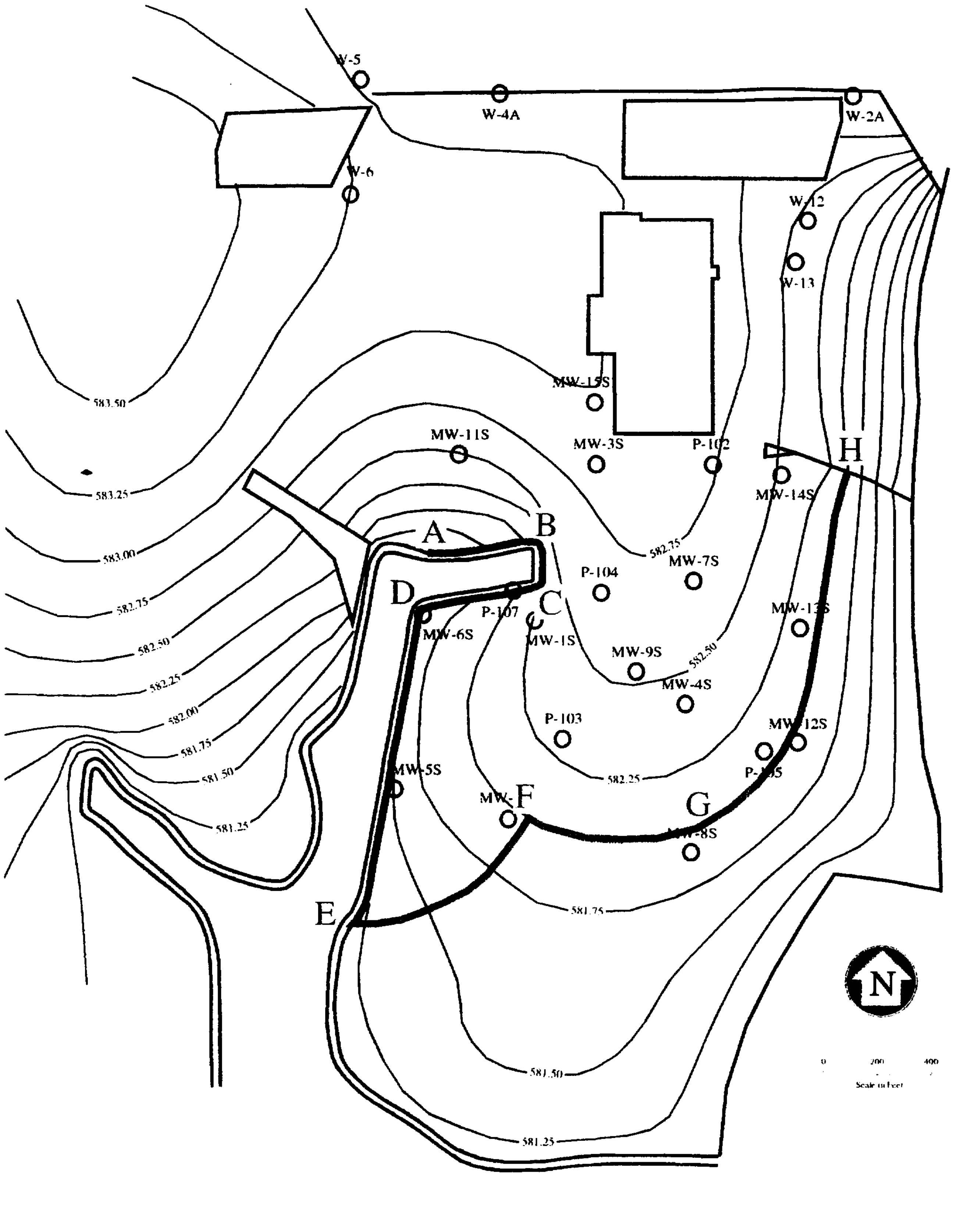


Figure 5-C-14

LOCATION OF SEGMENTS
FOR COMPUTATION OF TOTAL DISCHARGE
USING SITE CALIBRATED SLAEM GROUNDWATER MODEL

Attachment 5-C-1

ATTACHMENT 5-C-1

DESCRIPTION OF SLAEM COMPUTER PROGRAM

The conceptual hydrogeologic model was used to develop a groundwater flow model using the SLAEM computer program. SLAEM can be used to simulate groundwater flow and solute transport for a single-aquifer system.

SLAEM simulates hydrologic and hydrogeologic features that control groundwater flow using analytic functions called analytic elements. Boundary conditions are specified at known points in the flow domain (e.g., discharge from remedial wells or water elevations at a series of points defining surface water bodies such as lakes and rivers). Each boundary condition corresponds to the addition of an equation to a system of equations defined by the analytic functions of the model. This system of equations is solved to define unknown model parameters. Once the system of equations is solved, the approximate analytic solution to the complex groundwater potential is known. Piezometric levels and flow velocities can be obtained from this complex groundwater potential for any point within the aquifer.

The analytic element method of groundwater modeling takes advantage of recent improvements in computer technology. Prior to the development of high-speed, high-memory personal computers, the method of solving large systems of equations was impractical. Consequently, model development has traditionally involved numerical modeling methods (e.g., finite-element and finite-difference methods) which require discretization of the aquifer into a grid system and approximate solutions to a series of complex differential equations. The analytic element method represents a major improvement in groundwater modeling in that the groundwater flow domain is infinite in areal extent and does not require discretization.

The SLAEM computer program is being used by Oak Ridge National Laboratories, Los Alamos National Laboratories, Lawrence Livermore National Laboratories, Battelle Northwest Laboratories, Sandia National Laboratory, U.S. Geological Survey, U.S. Environmental Protection Agency, State agencies throughout Minnesota, and many private companies. SLAEM has been used to successfully support litigation. The Netherlands is extensively using a more sophisticated version using multiple aquifer layers in the development of a groundwater resource model for the entire country.

Attachment 5-C-2

```
*****************************************************************
*                                                               *
*          B A R R   E N G I N E E R I N G   C O .              *
*                                                               *
*       Single-Layer Analytic Element Method (SLAEM) Model      *
*                                                               *
*              File:  WCPCAL                                    *
*                                                               *
*      Element Type:  Switch Module                             *
*       Element Use:  Input CALL file for calling               *
*                     element data files (site calibration).    *
*                                                               *
*              Date:  March 19, 1994                            *
*     Revision Date:                                            *
*                                                               *
*****************************************************************
 CALL WCPAQU.DAT   * Data file for defining aquifer properties.
 CALL WCPWIN.DAT   * Data file for defining model window.
 CALL WCPLLIN.DAT  * Data file for defining linear linesink elements.
 CALL WCPCLIN.DAT  * Data file for defining constant linesink elements.
 CALL WCPLK.DAT    * Data file for defining curvilinear leaky element.
 CALL WCPHD.DAT    * Data file for defining curvilinear head element.
 CALL WCPIM.DAT    * Data file for defining curvilinear impermeable elements.
 CALL WCPARE.DAT   * Data file for defining given strength areal elements.
 CALL WCPMONWL.MAP * [Optional] Map file for defining monitoring wells.
 END
```

```
*******************************************************************
*                                                                 *
*            B A R R   E N G I N E E R I N G   C O .              *
*                                                                 *
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*                                                                 *
*              File:  WCPCALS1                                    *
*                                                                 *
*      Element Type:  Switch Module                               *
*       Element Use:  Input CALL file for calling                 *
*                     element data files (simulation).            *
*                                                                 *
*              Date:  March 19, 1994                              *
*     Revision Date:                                              *
*                                                                 *
*******************************************************************
 CALL WCPAQU.DAT    * Data file for defining aquifer properties.
 CALL WCPWIN.DAT    * Data file for defining model window.
 CALL WCPLLIN.DAT   * Data file for defining linear linesink elements.
 CALL WCPCLIN.DAT   * Data file for defining constant linesink elements.
 CALL WCPLK_S.DAT   * Data file for defining curvilinear leaky element.
 CALL WCPHD_S.dat   * Data file for defining curvilinear head element.
 CALL WCPIM_S.DAT   * Data file for defining curvilinear impermeable elements.
 CALL WCPARE_S.DAT * Data file for defining given strength areal elements.
 CALL WCPMONWL.MAP * [Optional] Map file for defining monitoring wells.
 END
```

```
**************************************************************
*                                                            *
*            B A R R   E N G I N E E R I N G   C O .         *
*                                                            *
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*                                                            *
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*                    element data files (simulation).        *
*                                                            *
*              Date:  March 19, 1994                         *
*     Revision Date:                                         *
*                                                            *
**************************************************************
CALL WCPAQU.DAT   * Data file for defining aquifer properties.
CALL WCPWIN.DAT   * Data file for defining model window.
CALL WCPLLIN.DAT  * Data file for defining linear linesink elements.
CALL WCPCLIN.DAT  * Data file for defining constant linesink elements.
CALL WCPLK_S.DAT  * Data file for defining curvilinear leaky element.
CALL WCPHD_S.dat  * Data file for defining curvilinear head element.
CALL WCPIM_S.DAT  * Data file for defining curvilinear impermeable elements.
CALL WCPARE_S.DAT * Data file for defining given strength areal elements.
CALL WCPPON_S.DAT * Data file for defining given strength areal elements.
CALL WCPMONWL.MAP * [Optional] Map file for defining monitoring wells.
END
```

```
*******************************************************************
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*        Element Use:  Defines global hydraulic conductivity,     *
*                      thickness, base, and porosity.  Also       *
*                      defines the reference point.               *
*                                                                 *
*               Date:  March 19, 1994                             *
*      Revision Date:                                             *
*                                                                 *
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 RET
AQU
 BASE   557.
 THICK   33.
 PERM    31.
 POR       .38
RET
REF
  20000 0 581.1
 RET
RET
SWI
 BACK
```

```
********************************************************************
*                                                                  *
*           B A R R   E N G I N E E R I N G   C O .               *
*                                                                  *
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*                                                                  *
*      Element Type:  Window Module                                *
*       Element Use:  Defines window.                              *
*                                                                  *
*              Date:  March 19, 1994                               *
*     Revision Date:                                               *
*                                                                  *
********************************************************************
 RET
WIN -500 -1000 3500 3500
RET
SWI
 BACK
```

```
*******************************************************************
*                                                                 *
*             B A R R   E N G I N E E R I N G   C O .             *
*                                                                 *
*        Single-Layer Analytic Element Method (SLAEM) Model       *
*                                                                 *
*                File:  WCPLLIN.DAT                               *
*                                                                 *
*       Element Type:  Linesink (Linear) Module                   *
*        Element Use:  Defines linear strength linesink           *
*                      elements that are used to simulate         *
*                      drainages.                                 *
*                                                                 *
*                Date:  March 19, 1994                            *
*      Revision Date:                                             *
*                                                                 *
*******************************************************************
 RET
LINE LINE
 HEAD
* NORTH DRAINAGE CREEK
  1003.5 3189.0 582.84
  1340.2 3192.0 582.84
  1646.7 3198.0 582.84
  1943.7 3200.7 582.84
  2221.7 3196.8 582.84
  2455.1 3206.9 582.84
  2666.4 3202.5 582.84
  2857.1 3196.3 582.84
  2961.9 3019.3 582.84
  3086.0 2821.9 581
 COM
 HEAD
* SOUTH DRAINAGE CREEK
  2568.9 1873.7 582.49
  2787.1 1804.2 581.76
  2960.9 1726.4 581
 RET
RET
SWI
 BACK
```

```
*****************************************************************
*                                                               *
*           B A R R   E N G I N E E R I N G   C O .             *
*                                                               *
*     Single-Layer Analytic Element Method (SLAEM) Model        *
*                                                               *
*             File:  WCPCLIN.DAT                                *
*                                                               *
*     Element Type:  Linesink (Constant) Module                 *
*      Element Use:  Defines constant strength linesink         *
*                    elements that are used to simulate         *
*                    lake and ponding area.                     *
*                                                               *
*             Date:  March 19, 1994                             *
*    Revision Date:                                             *
*                                                               *
*****************************************************************
 RET
LINE
 HEAD
* SOUTH DRAINAGE CREEK BASIN
  2438.9 1927.6 2556.4 1890.0 582.49
  2556.4 1890.0 2437.5 1875.2 582.49
  2437.5 1875.2 2438.9 1927.6 582.49
* MICHIGAN LAKE
  2270.9 -649.7 2298.8 -396.9 581
  2298.8 -396.9 2371.4 -170.7 581
  2371.4 -170.7 2476.0   30.3 581
  2476.0   30.3 2583.8  220.3 581
  2583.8  220.3 2685.7  375.3 581
  2685.7  375.3 2897.1  351.8 581
  2897.1  351.8 3069.0  315.3 581
  3069.0  315.3 3060.2  588.4 581
  3060.2  588.4 3005.8  802.3 581
  3005.8  802.3 2986.5 1008.6 581
  2986.5 1008.6 2972.0 1202.3 581
  2972.0 1202.3 2968.5 1419.9 581
  2968.5 1419.9 2966.7 1612.0 581
  2966.7 1612.0 2972.5 1850.4 581
  2972.5 1850.4 2992.7 2076.1 581
  2992.7 2076.1 2982.8 2288.8 581
  2982.8 2288.8 3001.6 2495.5 581
  3001.6 2495.5 3049.2 2677.0 581
  3049.2 2677.0 3104.1 2931.6 581
 RET
RET
SWI
 BACK
```

```
****************************************************************
*                                                              *
*           B A R R   E N G I N E E R I N G   C O .           *
*                                                              *
*      Single-Layer Analytic Element Method (SLAEM) Model      *
*                                                              *
*              File:  WCPLK.DAT                                *
*                                                              *
*      Element Type:  Curvilinear (Leaky) Element              *
*       Element Use:  Defines leaky conditions along           *
*                     curvilinear boundary of harbor.          *
*                                                              *
*              Date:  March 19, 1994                           *
*     Revision Date:                                           *
*                                                              *
****************************************************************
 RET
CUREL
 TOL 100
 OPEN
 LEAK 20 1 0.3
   432.41   -391.58    1  1  0.3   [1]
   429.58   -255.01    1  1  0.3   [2]
   428.72   -159.71    1  1  0.3   [3]
   429.50    -70.76    1  1  0.3   [4]
   422.25     27.65    1  1  0.3   [5]
   416.61    124.49    1  1  0.3   [6]
   398.16    232.33    1  1  0.3   [7]
   314.90    306.23    1  1  0.3   [8]
   254.01    364.45    1  1  0.3   [9]
   177.24    422.52    1  1  0.3   [10]
   118.02    472.81    1  1  0.3   [11]
    76.32    516.91    1  1  0.3   [12]
    22.00    551.00    1  1  0.3   [13]
   -18.08    593.89    1  1  0.3   [14]
   -29.46    622.37    1  1  0.3   [15]
   -33.04    666.82    1  1  0.3   [16]
   -19.15    711.42    1  1  0.3   [17]
   -22.76    759.03    1  1  0.3   [18]
   -11.94    792.49    1  1  0.3   [19]
     3.86    800.57    1  1  0.3   [20]
    45.45    767.60    1  1  0.3   [21]
    91.87    728.31    1  1  0.3   [22]
   139.95    681.09    1  1  0.3   [23]
   197.50    640.31    1  1  0.3   [24]
   258.45    575.74    1  1  0.3   [25]
   322.41    528.67    1  1  0.3   [26]
   386.50    467.31    1  1  0.3   [27]
   437.70    426.47    1  1  0.3   [28]
   511.16    382.66    1  1  0.3   [29]
   609.79    366.08    1  1  0.3   [30]
   712.80    392.43    1  1  0.3   [31]
   761.49    453.23    1  1  0.3   [32]
   808.54    518.78    1  1  0.3   [33]
   788.48    629.79    1  1  0.3   [34]
   771.93    702.70    1  1  0.3   [35]
   755.36    778.79    1  1  0.3   [36]
   746.67    861.31    1  1  0.3   [37]
   820.76    923.93    1  1  0.3   [38]
   890.26    965.86    1  1  0.3   [39]
   917.70   1093.18    1  1  0.3   [40]
```

954.37	1253.94	5	1	0.3	[41]
990.68	1452.81	5	1	0.3	[42]
1002.86	1511.69	5	1	0.3	[43]
1031.12	1548.48	5	1	0.3	[44]
1091.44	1552.21	5	1	0.3	[45]
1169.32	1546.56	5	1	0.3	[46]
1234.57	1532.85	10	1	0.3	[47]
1340.93	1540.17	10	1	0.3	[48]
1417.05	1553.57	15	1	0.3	[49]
1510.62	1568.71	15	1	0.3	[50]
1583.63	1575.73	20	1	0.3	[51]
1609.09	1569.60	20	1	0.3	[52]
1618.80	1550.63	710	2	0.3	[53]
1624.43	1526.86	710	2	0.3	[54]
1625.58	1485.69	710	2	0.3	[55]
1626.06	1450.63	710	2	0.3	[56]
1629.54	1417.31	20	1	0.3	[57]
1593.09	1407.44	20	1	0.3	[58]
1518.53	1397.24	20	1	0.3	[59]
1413.92	1372.46	20	1	0.3	[60]
1298.21	1346.00	11	1	0.3	[61]
1214.09	1338.89	11	1	0.3	[62]
1183.96	1333.85	11	1	0.3	[63]
1176.42	1289.30	11	1	0.3	[64]
1140.20	1079.31	11	1	0.3	[65]
1091.58	835.85	11	1	0.3	[66]
1040.36	528.82	9	1	0.3	[67]
999.16	342.61	9	1	0.3	[68]
985.67	253.54	9	1	0.3	[69]
932.17	197.46	9	1	0.3	[70]
905.78	130.51	9	1	0.3	[71]
873.82	-23.84	9	1	0.3	[72]
869.95	-122.36	9	1	0.3	[73]
885.29	-238.17	5	1	0.3	[74]
970.39	-339.06	5	1	0.3	[75]
1089.02	-458.70	5	1	0.3	[76]
1164.36	-534.26	5	1	0.3	[77]
1299.99	-602.92	2	1	0.3	[78]
1426.01	-662.13	2	1	0.3	[79]
1683.26	-655.04	2	1	0.3	[80]
1877.09	-659.63	2	1	0.3	[81]
2131.12	-647.80	2	1	0.3	[82]
2272.43	-641.75	2	1	0.3	[83]

```
 COM
RET
SWI
 BACK
```

```
*******************************************************************
*                                                                 *
*          B A R R   E N G I N E E R I N G   C O .                *
*                                                                 *
*      Single-Layer Analytic Element Method (SLAEM) Model         *
*                                                                 *
*               File:  WCPHD.DAT                                  *
*                                                                 *
*       Element Type:  Curvilinear (Head) Element                 *
*        Element Use:  Defines water elevation along              *
*                      curvilinear boundary of harbor.            *
*                                                                 *
*               Date:  March 19, 1994                             *
*      Revision Date:                                             *
*                                                                 *
*******************************************************************
 RET
CUREL
 TOL 100
 OPEN
 HEAD 581 1
  462.41  -390.97  581  1  [1]
  459.58  -254.53  581  1  [2]
  458.72  -159.70  581  1  [3]
  459.49   -69.73  581  1  [4]
  452.19    29.63  581  1  [5]
  446.41   128.00  581  1  [6]
  424.34   246.99  581  1  [7]
  335.17   328.35  581  1  [8]
  273.37   387.37  581  1  [9]
  195.94   445.99  581  1  [10]
  138.51   494.73  581  1  [11]
   95.26   540.18  581  1  [12]
   40.96   574.25  581  1  [13]
    6.24   611.44  581  1  [14]
   -0.08   628.40  581  1  [15]
   -3.25   663.37  581  1  [16]
   10.66   708.10  581  1  [17]
    7.12   756.38  581  1  [18]
   10.85   768.98  581  1  [19]
   15.80   773.06  581  1  [20]
   23.75   771.85  581  1  [21]
   71.62   706.18  581  1  [22]
  120.76   658.04  581  1  [23]
  177.58   617.90  581  1  [24]
  238.46   553.38  581  1  [25]
  303.03   505.78  581  1  [26]
  366.61   444.86  581  1  [27]
  420.85   401.66  581  1  [28]
  501.23   354.36  581  1  [29]
  611.25   336.12  581  1  [30]
  725.07   371.12  581  1  [31]
  786.86   438.79  581  1  [32]
  839.00   509.34  581  1  [33]
  817.90   635.65  581  1  [34]
  801.22   709.22  581  1  [35]
  784.99   783.52  581  1  [36]
  774.03   848.99  581  1  [37]
  838.42   899.68  581  1  [38]
  916.30   950.95  581  1  [39]
  946.99  1086.66  581  1  [40]
  983.77  1247.97  581  1  [41]
```

```
    1020.17   1447.26   581   1   [42]
    1030.49   1500.01   581   1   [43]
    1043.60   1521.20   581   1   [44]
    1091.02   1522.21   581   1   [45]
    1165.30   1516.83   581   1   [46]
    1233.45   1502.87   581   1   [47]
    1344.31   1510.36   581   1   [48]
    1422.03   1523.99   581   1   [49]
    1514.58   1538.97   581   1   [50]
    1583.90   1545.73   581   1   [51]
    1591.66   1545.18   581   1   [52]
    1595.97   1539.61   581   1   [53]
    1596.65   1512.16   581   1   [54]
    1596.65   1475.41   581   1   [55]
    1596.16   1448.22   581   1   [56]
    1594.76   1439.62   581   1   [57]
    1587.75   1436.96   581   1   [58]
    1512.78   1426.68   581   1   [59]
    1407.12   1401.68   581   1   [60]
    1293.24   1375.59   581   1   [61]
    1210.92   1368.72   581   1   [62]
    1160.07   1352.00   581   1   [63]
    1146.85   1294.38   581   1   [64]
    1110.71   1084.83   581   1   [65]
    1062.06    841.20   581   1   [66]
    1010.87    534.35   581   1   [67]
     969.74    348.46   581   1   [68]
     958.44    266.11   581   1   [69]
     907.02    213.80   581   1   [70]
     876.77    138.16   581   1   [71]
     844.12    -19.64   581   1   [72]
     840.00   -123.97   581   1   [73]
     858.08   -250.79   581   1   [74]
     948.36   -359.42   581   1   [75]
    1067.74   -479.85   581   1   [76]
    1147.43   -559.03   581   1   [77]
    1286.82   -629.87   581   1   [78]
    1421.97   -691.86   581   1   [79]
    1683.43   -685.04   581   1   [80]
    1877.57   -689.63   581   1   [81]
    2132.48   -677.77   581   1   [82]
    2272.43   -671.72   581   1   [83]
    COM
  RET
  SWI
    BACK
```

```
*****************************************************************
*                                                               *
*          B A R R   E N G I N E E R I N G   C O .              *
*                                                               *
*       Single-Layer Analytic Element Method (SLAEM) Model      *
*                                                               *
*              File:  WCPIM.DAT                                 *
*                                                               *
*      Element Type:  Curvilinear (Impermeable) Element         *
*       Element Use:  Defines no flow conditions along          *
*                     curvilinear boundaries of containment     *
*                     cells and foundation.                     *
*                                                               *
*              Date:  March 19, 1994                            *
*     Revision Date:                                            *
*                                                               *
*****************************************************************
 RET  *  Impermeable Segments For Containment Cell 1
CURE
 OPEN
 IMP
   494.27 3122.47
   545.72 3124.52
   622.88 3127.60
   751.49 3132.74
   880.10 3137.87
   957.27 3140.95
  1008.72 3143.01
 COM
RET
CURE
 OPEN
 IMP
  1008.72 3143.01
   993.56 3115.23
   970.83 3073.57
   932.94 3004.13
   895.05 2934.69
   872.32 2893.03
   857.17 2865.26
 COM
RET
CURE
 OPEN
 IMP
   857.17 2865.26
   816.98 2864.89
   756.71 2864.35
   656.25 2863.44
   555.79 2862.53
   495.52 2861.98
   455.34 2861.62
 COM
RET
CURE
 OPEN
 IMP
   455.34 2861.62
   455.07 2874.00
   454.66 2892.58
   453.98 2923.55
   453.30 2954.52
```

```
    452.90 2973.10
    452.63 2985.49
  COM
 RET
 CURE
  OPEN
  IMP
    452.63 2985.49
    456.79 2999.18
    463.04 3019.73
    473.45 3053.98
    483.86 3088.22
    490.11 3108.77
    494.27 3122.47
  COM
 RET  *  Impermeable Segments For Containment Cell 2
 CURE
  OPEN
  IMP
   1932.94 3167.27
   1974.55 3167.01
   2036.98 3166.62
   2141.03 3165.98
   2245.07 3165.33
   2307.50 3164.94
   2349.12 3164.69
  COM
 RET
 CURE
  OPEN
  IMP
   2349.12 3164.69
   2385.64 3165.49
   2440.43 3166.71
   2531.74 3168.73
   2623.05 3170.75
   2677.84 3171.96
   2714.37 3172.77
  COM
 RET
 CURE
  OPEN
  IMP
   2714.37 3172.77
   2715.08 3164.04
   2716.15 3150.94
   2717.94 3129.12
   2719.73 3107.29
   2720.80 3094.2
   2721.52 3085.47
  COM
 RET
 CURE
  OPEN
  IMP
   2721.52 3085.47
   2715.34 3065.56
   2706.08 3035.69
   2690.65 2985.92
   2675.22 2936.14
   2665.96 2906.28
   2659.79 2886.37
```

```
 COM
RET
CURE
 OPEN
 IMP
  2659.79 2886.37
  2625.32 2886.05
  2573.62 2885.58
  2487.46 2884.80
  2401.30 2884.02
  2349.60 2883.55
  2315.14 2883.24
 COM
RET
CURE
 OPEN
 IMP
  2315.14 2883.24
  2276.38 2883.52
  2218.24 2883.95
  2121.34 2884.66
  2024.44 2885.37
  1966.30 2885.79
  1927.55 2886.08
 COM
RET
CURE
 OPEN
 IMP
  1927.55 2886.08
  1928.08 2914.19
  1928.89 2956.37
  1930.24 3026.67
  1931.59 3096.97
  1932.40 3139.15
  1932.94 3167.27
 COM
RET  * Impermeable Segments For Containment at Old Slip
CURE
 OPEN
 IMP
  1845.01 2529.54
  1845.01 2552.56
  1845.01 2587.11
  1845.01 2644.68
  1845.01 2702.25
  1845.01 2736.79
  1845.01 2759.82
 COM
RET
CURE
 OPEN
 IMP
  1845.01 2759.82
  1859.72 2759.82
  1881.80 2759.82
  1918.60 2759.82
  1955.40 2759.82
  1977.48 2759.82
  1992.2  2759.82
 COM
RET
```

```
CURE
 OPEN
 IMP
  1992.2  2759.82
  1992.2  2757.25
  1992.2  2753.40
  1992.2  2746.99
  1992.2  2740.58
  1992.2  2736.73
  1992.2  2734.17
 COM
RET
CURE
 OPEN
 IMP
  1992.2  2734.17
  2017.80 2734.17
  2056.21 2734.17
  2120.22 2734.17
  2184.23 2734.17
  2222.63 2734.17
  2248.24 2734.17
 COM
RET
CURE
 OPEN
 IMP
  2248.24 2734.17
  2248.24 2716.93
  2248.24 2691.07
  2248.24 2647.98
  2248.24 2604.89
  2248.24 2579.03
  2248.24 2561.8
 COM
RET
CURE
 OPEN
 IMP
  2248.24 2561.8
  2250.61 2561.8
  2254.18 2561.8
  2260.13 2561.8
  2266.08 2561.8
  2269.65 2561.8
  2272.03 2561.8
 COM
RET
CURE
 OPEN
 IMP
  2272.03 2561.8
  2272.03 2558.47
  2272.03 2553.49
  2272.03 2545.19
  2272.03 2536.89
  2272.03 2531.91
  2272.03 2528.59
 COM
RET
CURE
 OPEN
```

```
 IMP
  2272.03 2528.59
  2269.65 2528.59
  2266.08 2528.59
  2260.13 2528.59
  2254.18 2528.59
  2250.61 2528.59
  2248.24 2528.59
 COM
RET
CURE
 OPEN
 IMP
  2248.24 2528.59
  2248.24 2514.28
  2248.24 2492.82
  2248.24 2457.06
  2248.24 2421.29
  2248.24 2399.83
  2248.24 2385.53
 COM
RET
CURE
 OPEN
 IMP
  2248.24 2385.53
  2248.24 2371.22
  2248.24 2349.76
  2248.24 2314
  2248.24 2278.23
  2248.24 2256.77
  2248.24 2242.47
 COM
RET
CURE
 OPEN
 IMP
  2248.24 2242.47
  2248.24 2214.83
  2248.24 2173.38
  2248.24 2104.30
  2248.24 2035.22
  2248.24 1993.77
  2248.24 1966.14
 COM
RET
CURE
 OPEN
 IMP
  2248.24 1966.14
  2230.51 1966.14
  2203.93 1966.14
  2159.63 1966.14
  2115.33 1966.14
  2088.75 1966.14
  2071.03 1966.14
 COM
RET
CURE
 OPEN
 IMP
  2071.03 1966.14
```

```
    2052.91 1966.14
    2025.73 1966.14
    1980.43 1966.14
    1935.13 1966.14
    1907.95 1966.14
    1889.84 1966.14
  COM
 RET
 CURE
  OPEN
  IMP
    1889.84 1966.14
    1889.84 1978.68
    1889.84 1997.50
    1889.84 2028.87
    1889.84 2060.24
    1889.84 2079.06
    1889.84 2091.61
  COM
 RET
 CURE
  OPEN
  IMP
    1889.84 2091.61
    1889.84 2107.80
    1889.84 2132.09
    1889.84 2172.57
    1889.84 2213.05
    1889.84 2237.34
    1889.84 2253.54
  COM
 RET
 CURE
  OPEN
  IMP
    1889.84 2253.54
    1880.18 2253.54
    1865.69 2253.54
    1841.55 2253.54
    1817.41 2253.54
    1802.92 2253.54
    1793.27 2253.54
  COM
 RET
 CURE
  OPEN
  IMP
    1793.27 2253.54
    1793.27 2274.15
    1793.27 2305.07
    1793.27 2356.60
    1793.27 2408.13
    1793.27 2439.05
    1793.27 2459.67
  COM
 RET
 CURE
  OPEN
  IMP
    1793.27 2459.67
    1798.44 2459.67
    1806.20 2459.67
```

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   1819.14 2459.67
   1832.07 2459.67
   1839.83 2459.67
   1845.01 2459.67
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 RET
 CURE
  OPEN
  IMP
   1845.01 2459.67
   1845.01 2466.65
   1845.01 2477.13
   1845.01 2494.60
   1845.01 2512.07
   1845.01 2522.55
   1845.01 2529.54
  COM
 RET  * Impermeable Segments For Foundation
 CURE
  OPEN
  IMP
   546.21 1772.81
   549.80 1779.83
   555.19 1790.36
   564.16 1807.92
   573.14 1825.47
   578.52 1836.00
   582.11 1843.03
  COM
 RET
 CURE
  OPEN
  IMP
   582.11 1843.03
   608.31 1826.43
   647.61 1801.53
   713.11 1760.03
   778.61 1718.53
   817.91 1693.63
   844.11 1677.03
  COM
 RET
 CURE
  OPEN
  IMP
   844.11 1677.03
   860.09 1666.05
   884.07 1649.59
   924.02 1622.16
   963.98 1594.73
   987.95 1578.27
  1003.94 1567.3
  COM
 RET
 CURE
  OPEN
  IMP
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   997.68 1538.81
   988.30 1496.07
   972.67 1424.85
   957.03 1353.63
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    941.40 1282.41
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RET
CURE
  OPEN
  IMP
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    934.04 1305.85
    923.00 1341.01
    904.60 1399.61
    886.20 1458.21
    875.16 1493.37
    867.80 1516.82
  COM
RET
CURE
  OPEN
  IMP
    867.80 1516.82
    852.57 1531.77
    829.74 1554.2
    791.67 1591.58
    753.61 1628.96
    730.77 1651.38
    715.55 1666.34
  COM
RET
CURE
  OPEN
  IMP
    715.55 1666.34
    698.61 1676.98
    673.21 1692.95
    630.88 1719.57
    588.55 1746.19
    563.15 1762.16
    546.21 1772.81
  COM
RET
SWI
  BACK
```

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*****************************************************************
*                                                               *
*           B A R R   E N G I N E E R I N G   C O .            *
*                                                               *
*     Single-Layer Analytic Element Method (SLAEM) Model       *
*                                                               *
*             File:  WCPARE.DAT                                 *
*                                                               *
*     Element Type:  Areal Element Module                       *
*      Element Use:  Defines given strength areal elements      *
*                    that simulate infiltration at the top      *
*                    of the aquifer.                            *
*                                                               *
*             Date:  March 19, 1994                             *
*    Revision Date:                                             *
*                                                               *
*****************************************************************
 RET
ARE
 DRAW OFF
 GIVEN
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  -153   946   -70  1250   140  1250   108  1000  -0.00310  [2]
   -94   907  -153   946   108  1000    77   751  -0.00310  [3]
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  -280  2150  -280  2600   140  2600   140  2150  -0.00310  [7]
  -280  2600  -280  3050   140  3050   140  2600  -0.00310  [8]
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   437   424   455   575   560   575   560   462  -0.00310  [18]
   509   388   437   424   560   462   563   373  -0.00310  [19]
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   560   462   560   575   665   575   665   462  -0.00310  [38]
   665   462   665   575   794   573   770   462  -0.00310  [39]
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   601   684   612   575   665   575   665   687  -0.00310  [41]
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665	912	665	968	717	968	716	911	-0.00310	[47]
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716	911	717	968	769	967	774	900	-0.00310	[50]
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875	1137	875	1193	938	1191	927	1137	-0.00310	[61]
875	1193	875	1250	955	1249	938	1191	-0.00310	[62]
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769	967	770	1025	822	1025	822	968	-0.00310	[66]
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2240	-268	2240	-212	2352	-211	2329	-269	-0.00310	[212]
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2240	-100	2240	12	2345	12	2345	-100	-0.00310	[215]
2240	12	2240	125	2345	125	2345	12	-0.00310	[216]
2345	12	2345	125	2450	125	2459	8	-0.00310	[217]
2345	-100	2345	12	2459	8	2399	-99	-0.00310	[218]
2240	125	2240	350	2450	350	2450	125	-0.00310	[219]
2450	125	2450	237	2584	234	2524	120	-0.00310	[220]
2450	237	2450	350	2555	350	2584	234	-0.00310	[221]
2584	234	2555	350	2681	374	2633	294	-0.00310	[222]
2459	8	2450	125	2524	120	2496	68	-0.00310	[223]
2240	350	2240	575	2450	575	2450	350	-0.00310	[224]
2240	575	2240	800	2450	800	2450	575	-0.00310	[225]
2450	575	2450	800	2660	800	2660	575	-0.00310	[226]
2450	350	2450	462	2555	462	2555	350	-0.00310	[227]

2450	462	2450	575	2555	575	2555	462	-0.00310	[228]
2555	462	2555	575	2660	575	2660	462	-0.00310	[229]
2555	350	2555	462	2660	462	2681	374	-0.00310	[230]
2240	800	2240	1250	2660	1250	2660	800	-0.00310	[231]
2240	1250	2240	1700	2660	1700	2660	1250	-0.00310	[232]
2660	1925	2240	1925	2240	2150	2660	2150	-0.00310	[233]
2660	1700	2240	1700	2240	1925	2660	1925	-0.00310	[234]
2240	2150	2240	2375	2450	2375	2450	2150	-0.00310	[235]
2240	2375	2240	2600	2450	2600	2450	2375	-0.00310	[236]
2450	2375	2450	2600	2660	2600	2660	2375	-0.00310	[237]
2450	2150	2450	2375	2660	2375	2660	2150	-0.00310	[238]
2240	2600	2240	2825	2450	2825	2450	2600	-0.00310	[239]
2240	2825	2239	2885	2314	2885	2345	2825	-0.00310	[240]
2345	2825	2314	2885	2449	2885	2450	2825	-0.00310	[241]
2450	2825	2449	2885	2540	2885	2555	2825	-0.00310	[242]
2555	2825	2540	2885	2659	2885	2660	2825	-0.00310	[243]
2450	2600	2450	2825	2660	2825	2660	2600	-0.00310	[244]
2238	3197	2449	3207	2449	3164	2239	3164	-0.00310	[245]
2449	3207	2660	3201	2636	3166	2449	3164	-0.00310	[246]
2681	374	2660	462	2765	462	2764	368	-0.00310	[247]
2660	462	2660	575	2765	575	2765	462	-0.00310	[248]
2765	462	2765	575	2870	575	2870	462	-0.00310	[249]
2764	368	2765	462	2870	462	2864	359	-0.00310	[250]
2660	575	2660	800	2870	800	2870	575	-0.00310	[251]
2870	575	2870	800	3005	798	3061	576	-0.00310	[252]
2864	359	2870	462	2975	462	2972	337	-0.00310	[253]
2870	462	2870	575	2975	575	2975	462	-0.00310	[254]
2975	462	2975	575	3061	576	3067	462	-0.00310	[255]
2972	337	2975	462	3067	462	3067	311	-0.00310	[256]
2660	800	2660	1025	2870	1025	2870	800	-0.00310	[257]
2660	1025	2660	1250	2870	1250	2870	1025	-0.00310	[258]
2870	1025	2870	1250	2973	1249	2985	1023	-0.00310	[259]
2870	800	2870	1025	2985	1023	3005	798	-0.00310	[260]
2660	1250	2660	1475	2870	1475	2870	1250	-0.00310	[261]
2660	1475	2660	1700	2870	1700	2870	1475	-0.00310	[262]
2870	1475	2870	1700	2970	1697	2970	1474	-0.00310	[263]
2870	1250	2870	1475	2970	1474	2973	1249	-0.00310	[264]
2660	1700	2660	1925	2870	1925	2870	1700	-0.00310	[265]
2660	1925	2660	2150	2870	2150	2870	1925	-0.00310	[266]
2870	1925	2870	2150	2987	2148	2985	1925	-0.00310	[267]
2870	1700	2870	1925	2985	1925	2970	1697	-0.00310	[268]
2660	2150	2660	2375	2870	2375	2870	2150	-0.00310	[269]
2660	2375	2660	2600	2870	2600	2870	2375	-0.00310	[270]
2870	2375	2870	2600	3031	2600	2977	2372	-0.00310	[271]
2870	2150	2870	2375	2977	2372	2987	2148	-0.00310	[272]
2660	2600	2660	2825	2870	2825	2870	2600	-0.00310	[273]
2660	2825	2659	2885	2688	2977	2765	2825	-0.00310	[274]
2688	2977	2720	3084	2944	3049	2907	2937	-0.00310	[275]
2765	2825	2688	2977	2907	2937	2870	2825	-0.00310	[276]
2870	2825	2944	3049	3023	2924	3087	2821	-0.00310	[277]
2870	2600	2870	2825	3087	2821	3031	2600	-0.00310	[278]
2636	3166	2660	3201	2714	3198	2714	3171	-0.00310	[279]
2714	3171	2714	3198	2855	3198	2899	3123	-0.00310	[280]
2720	3084	2714	3171	2899	3123	2944	3049	-0.00310	[281]

RET
RET
SWI
BACK

```
*****************************************************************
*                                                               *
*          B A R R   E N G I N E E R I N G   C O .              *
*                                                               *
*      Single-Layer Analytic Element Method (SLAEM) Model       *
*                                                               *
*              File:  WCPLK_S.DAT                               *
*                                                               *
*     Element Type:  Curvilinear (Leaky) Element                *
*      Element Use:  Defines leaky conditions along             *
*                    curvilinear boundary of harbor.            *
*                                                               *
*             Date:  March 19, 1994                             *
*    Revision Date:                                             *
*                                                               *
*****************************************************************
 RET
CUREL
 TOL 100
 OPEN
 LEAK 20 1 0.3
   432.41  -391.58    1  1  0.3  [1]
   429.58  -255.01    1  1  0.3  [2]
   428.72  -159.71    1  1  0.3  [3]
   429.50   -70.76    1  1  0.3  [4]
   422.25    27.65    1  1  0.3  [5]
   416.61   124.49    1  1  0.3  [6]
   398.16   232.33    1  1  0.3  [7]
   314.90   306.23    1  1  0.3  [8]
   254.01   364.45    1  1  0.3  [9]
   177.24   422.52    1  1  0.3  [10]
   118.02   472.81    1  1  0.3  [11]
    76.32   516.91    1  1  0.3  [12]
    22      551       1  1  0.3  [13]
   -18.08   593.89    1  1  0.3  [14]
   -29.46   622.37    1  1  0.3  [15]
   -33.04   666.82    1  1  0.3  [16]
   -19.15   711.42    1  1  0.3  [17]
   -22.76   759.03    1  1  0.3  [18]
   -11.94   792.49    1  1  0.3  [19]
     3.86   800.57    1  1  0.3  [20]
    45.45   767.6     1  1  0.3  [21]
    91.87   728.31    1  1  0.3  [22]
   139.95   681.09    1  1  0.3  [23]
   197.50   640.31    1  1  0.3  [24]
   258.45   575.74    1  1  0.3  [25]
   322.41   528.67    1  1  0.3  [26]
   386.50   467.31    1  1  0.3  [27]
   437.70   426.47    1  1  0.3  [28]
   511.16   382.66    1  1  0.3  [29]
   609.79   366.08    1  1  0.3  [30]
   712.80   392.43    1  1  0.3  [31]
   761.49   453.23    1  1  0.3  [32]
   808.54   518.78    1  1  0.3  [33]
   788.48   629.79    1  1  0.3  [34]
   771.93   702.70    1  1  0.3  [35]
   755.36   778.79    1  1  0.3  [36]
   746.67   861.31    1  1  0.3  [37]
   820.76   923.93    1  1  0.3  [38]
   890.26   965.86    1  1  0.3  [39]
   917.70  1093.18    1  1  0.3  [40]
   930.8   1152.6     1  1  0.3  [41]
```

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   949.82  1207.16    1   1   0.3   [42]
   960.08  1282.03    1   1   0.3   [43]
   927.50  1348.46    1   1   0.3   [44]
   901.04  1435.63    1   1   0.3   [45]
   866.6   1507.8     1   1   0.3   [46]
   815.21  1566.65    1   1   0.3   [47]
   721.77  1668.95    1   1   0.3   [48]
   642.2   1718.2     1   1   0.3   [49]
   579.0   1776.0     1   1   0.3   [50]
   570.8   1785.4     1   1   0.3   [51]
   572.8   1793.3     5   1   0.3   [52]
   575.8   1803.8     5   1   0.3   [53]
   584.4   1812.6     5   1   0.3   [54]
   607.6   1816.8     5   1   0.3   [55]
   624.0   1812.2     5   1   0.3   [56]
   696.2   1779.0    11   1   0.3   [57]
   747.89  1747.19   11   1   0.3   [58]
   845.72  1678.34   11   1   0.3   [59]
   968.2   1615.7    11   1   0.3   [60]
  1069.4   1588.2    11   1   0.3   [61]
  1169.32  1546.56   11   1   0.3   [62]
  1202.7   1525.8    11   1   0.3   [63]
  1209.9   1498.2    11   1   0.3   [64]
  1214.3   1443.2    11   1   0.3   [65]
  1194.0   1369.8    11   1   0.3   [66]
  1183.96  1333.85   11   1   0.3   [67]
  1176.42  1289.30   11   1   0.3   [68]
  1140.20  1079.31   11   1   0.3   [69]
  1091.58   835.85   11   1   0.3   [70]
  1040.36   528.82    9   1   0.3   [71]
   999.16   342.61    9   1   0.3   [72]
   985.67   253.54    9   1   0.3   [73]
   932.17   197.46    9   1   0.3   [74]
   905.78   130.51    9   1   0.3   [75]
   873.82   -23.84    9   1   0.3   [76]
   869.95  -122.36    9   1   0.3   [77]
   885.29  -238.17    5   1   0.3   [78]
   970.39  -339.06    5   1   0.3   [79]
  1089.02  -458.70    5   1   0.3   [80]
  1164.36  -534.26    5   1   0.3   [81]
  1299.99  -602.92    2   1   0.3   [82]
  1426.01  -662.13    2   1   0.3   [83]
  1683.26  -655.04    2   1   0.3   [84]
  1877.09  -659.63    2   1   0.3   [85]
  2131.12  -647.80    2   1   0.3   [86]
  2272.43  -641.75    2   1   0.3   [87]
 COM
RET
SWI
 BACK
```

```
*****************************************************************
*                                                               *
*            B A R R   E N G I N E E R I N G   C O .            *
*                                                               *
*     Single-Layer Analytic Element Method (SLAEM) Model        *
*                                                               *
*              File:  WCPHD_S.DAT                               *
*                                                               *
*      Element Type:  Curvilinear (Head) Element                *
*       Element Use:  Defines water elevation along             *
*                     curvilinear boundary of harbor.           *
*                                                               *
*              Date:  March 19, 1994                            *
*     Revision Date:                                            *
*                                                               *
*****************************************************************
 RET
CUREL
 TOL 100
 OPEN
 HEAD 581 1
  462.41  -390.97  581  1  [1]
  459.58  -254.53  581  1  [2]
  458.72  -159.70  581  1  [3]
  459.49   -69.73  581  1  [4]
  452.19    29.63  581  1  [5]
  446.41   128.00  581  1  [6]
  424.34   246.99  581  1  [7]
  335.17   328.35  581  1  [8]
  273.37   387.37  581  1  [9]
  195.94   445.99  581  1  [10]
  138.51   494.73  581  1  [11]
   95.26   540.18  581  1  [12]
   40.96   574.25  581  1  [13]
    6.24   611.44  581  1  [14]
   -0.08   628.40  581  1  [15]
   -3.25   663.37  581  1  [16]
   10.66   708.10  581  1  [17]
    7.12   756.38  581  1  [18]
   10.85   768.98  581  1  [19]
   15.80   773.06  581  1  [20]
   23.75   771.85  581  1  [21]
   71.62   706.18  581  1  [22]
  120.76   658.04  581  1  [23]
  177.58   617.90  581  1  [24]
  238.46   553.38  581  1  [25]
  303.03   505.78  581  1  [26]
  366.61   444.86  581  1  [27]
  420.85   401.66  581  1  [28]
  501.23   354.36  581  1  [29]
  611.25   336.12  581  1  [30]
  725.07   371.12  581  1  [31]
  786.86   438.79  581  1  [32]
  839.00   509.34  581  1  [33]
  817.90   635.65  581  1  [34]
  801.22   709.22  581  1  [35]
  784.99   783.52  581  1  [36]
  774.03   848.99  581  1  [37]
  838.42   899.68  581  1  [38]
  916.30   950.95  581  1  [39]
  947.02  1086.82  581  1  [40]
  959.68  1144.46  581  1  [41]
```

979.09	1200.54	581	1	[42]
989.72	1286.71	581	1	[43]
955.51	1359.22	581	1	[44]
929.06	1446.34	581	1	[45]
891.70	1524.24	581	1	[46]
837.53	1586.70	581	1	[47]
741.54	1691.52	581	1	[48]
660.20	1742.20	581	1	[49]
603.54	1781.54	581	1	[50]
601.84	1785.14	581	1	[51]
602.02	1786.65	581	1	[52]
602.41	1788.37	581	1	[53]
604.00	1789.24	581	1	[54]
605.52	1790.17	581	1	[55]
610.35	1790.17	581	1	[56]
640.89	1774.98	581	1	[57]
682.26	1752.43	581	1	[58]
731.15	1722.30	581	1	[59]
778.42	1694.31	581	1	[60]
830.35	1652.58	581	1	[61]
956.99	1587.87	581	1	[62]
1059.65	1579.83	581	1	[63]
1156.60	1519.39	581	1	[64]
1179.72	1506.52	581	1	[65]
1180.19	1494.03	581	1	[66]
1184.53	1446.89	581	1	[67]
1165.09	1377.82	581	1	[68]
1154.65	1340.25	581	1	[69]
1146.85	1294.38	581	1	[70]
1110.71	1084.83	581	1	[71]
1062.06	841.20	581	1	[72]
1010.87	534.35	581	1	[73]
969.74	348.46	581	1	[74]
958.44	266.11	581	1	[75]
907.02	213.80	581	1	[76]
876.77	138.16	581	1	[77]
844.12	-19.64	581	1	[78]
840.00	-123.97	581	1	[79]
858.08	-250.79	581	1	[80]
948.36	-359.42	581	1	[81]
1067.74	-479.85	581	1	[82]
1147.43	-559.03	581	1	[83]
1286.82	-629.87	581	1	[84]
1421.97	-691.86	581	1	[85]
1683.43	-685.04	581	1	[86]
1877.57	-689.63	581	1	[87]
2132.48	-677.77	581	1	[88]
2272.43	-671.72	581	1	[89]

COM
RET
SWI
BACK

```
*******************************************************************
*                                                                 *
*           B A R R   E N G I N E E R I N G   C O .               *
*                                                                 *
*       Single-Layer Analytic Element Method (SLAEM) Model        *
*                                                                 *
*              File:  WCPIM_S.DAT                                 *
*                                                                 *
*      Element Type:  Curvilinear (Impermeable) Element           *
*       Element Use:  Defines no flow conditions along            *
*                     curvilinear boundaries of containment       *
*                     cells and foundation.                       *
*                                                                 *
*              Date:  March 19, 1994                              *
*     Revision Date:                                              *
*                                                                 *
*******************************************************************
 RET  *  Impermeable Segments For Containment Cell 1
CURE
 OPEN
 IMP
   494.27 3122.47
   545.72 3124.52
   622.88 3127.60
   751.49 3132.74
   880.10 3137.87
   957.27 3140.95
  1008.72 3143.01
 COM
RET
CURE
 OPEN
 IMP
  1008.72 3143.01
   993.56 3115.23
   970.83 3073.57
   932.94 3004.13
   895.05 2934.69
   872.32 2893.03
   857.17 2865.26
 COM
RET
CURE
 OPEN
 IMP
   857.17 2865.26
   816.98 2864.89
   756.71 2864.35
   656.25 2863.44
   555.79 2862.53
   495.52 2861.98
   455.34 2861.62
 COM
RET
CURE
 OPEN
 IMP
   455.34 2861.62
   455.07 2874.00
   454.66 2892.58
   453.98 2923.55
   453.30 2954.52
```

```
    452.90 2973.10
    452.63 2985.49
  COM
 RET
 CURE
  OPEN
  IMP
    452.63 2985.49
    456.79 2999.18
    463.04 3019.73
    473.45 3053.98
    483.86 3088.22
    490.11 3108.77
    494.27 3122.47
  COM
 RET  *  Impermeable Segments For Containment Cell 2
 CURE
  OPEN
  IMP
   1932.94 3167.27
   1974.55 3167.01
   2036.98 3166.62
   2141.03 3165.98
   2245.07 3165.33
   2307.50 3164.94
   2349.12 3164.69
  COM
 RET
 CURE
  OPEN
  IMP
   2349.12 3164.69
   2385.64 3165.49
   2440.43 3166.71
   2531.74 3168.73
   2623.05 3170.75
   2677.84 3171.96
   2714.37 3172.77
  COM
 RET
 CURE
  OPEN
  IMP
   2714.37 3172.77
   2715.08 3164.04
   2716.15 3150.94
   2717.94 3129.12
   2719.73 3107.29
   2720.80 3094.2
   2721.52 3085.47
  COM
 RET
 CURE
  OPEN
  IMP
   2721.52 3085.47
   2715.34 3065.56
   2706.08 3035.69
   2690.65 2985.92
   2675.22 2936.14
   2665.96 2906.28
   2659.79 2886.37
```

```
 COM
RET
CURE
 OPEN
 IMP
  2659.79 2886.37
  2625.32 2886.05
  2573.62 2885.58
  2487.46 2884.80
  2401.30 2884.02
  2349.60 2883.55
  2315.14 2883.24
 COM
RET
CURE
 OPEN
 IMP
  2315.14 2883.24
  2276.38 2883.52
  2218.24 2883.95
  2121.34 2884.66
  2024.44 2885.37
  1966.30 2885.79
  1927.55 2886.08
 COM
RET
CURE
 OPEN
 IMP
  1927.55 2886.08
  1928.08 2914.19
  1928.89 2956.37
  1930.24 3026.67
  1931.59 3096.97
  1932.40 3139.15
  1932.94 3167.27
 COM
RET  * Impermeable Segments For Containment at Old Slip
CURE
 OPEN
 IMP
  1845.01 2529.54
  1845.01 2552.56
  1845.01 2587.11
  1845.01 2644.68
  1845.01 2702.25
  1845.01 2736.79
  1845.01 2759.82
 COM
RET
CURE
 OPEN
 IMP
  1845.01 2759.82
  1859.72 2759.82
  1881.80 2759.82
  1918.60 2759.82
  1955.40 2759.82
  1977.48 2759.82
  1992.2  2759.82
 COM
RET
```

```
CURE
 OPEN
 IMP
  1992.2   2759.82
  1992.2   2757.25
  1992.2   2753.40
  1992.2   2746.99
  1992.2   2740.58
  1992.2   2736.73
  1992.2   2734.17
 COM
RET
CURE
 OPEN
 IMP
  1992.2   2734.17
  2017.80 2734.17
  2056.21 2734.17
  2120.22 2734.17
  2184.23 2734.17
  2222.63 2734.17
  2248.24 2734.17
 COM
RET
CURE
 OPEN
 IMP
  2248.24 2734.17
  2248.24 2716.93
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 OPEN
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 COM
RET
CURE
 OPEN
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 COM
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CURE
 OPEN
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   2248.24 2492.82
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  1817.41 2253.54
  1802.92 2253.54
  1793.27 2253.54
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  1793.27 2274.15
  1793.27 2305.07
  1793.27 2356.60
  1793.27 2408.13
  1793.27 2439.05
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  1798.44 2459.67
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    1845.01 2494.60
    1845.01 2512.07
    1845.01 2522.55
    1845.01 2529.54
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RET
SWI
  BACK
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*                                                                *
*            B A R R   E N G I N E E R I N G   C O .             *
*                                                                *
*      Single-Layer Analytic Element Method (SLAEM) Model        *
*                                                                *
*               File:  WCPARE_S.DAT                              *
*                                                                *
*       Element Type:  Areal Element Module                      *
*        Element Use:  Defines given strength areal elements     *
*                      that simulate infiltration at the top     *
*                      of the aquifer.                           *
*                                                                *
*               Date:  March 19, 1994                            *
*      Revision Date:                                            *
*                                                                *
******************************************************************
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 DRAW OFF
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   -94   907  -153   946   108  1000    77   751  -0.00310  [3]
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  -280  2600  -280  3050   140  3050   140  2600  -0.00310  [8]
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   560   462   560   575   665   575   665   462  -0.00310  [38]
   665   462   665   575   794   573   770   462  -0.00310  [39]
   681   363   665   462   770   462   732   399  -0.00310  [40]
   601   684   612   575   665   575   665   687  -0.00310  [41]
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717	968	717	1025	770	1025	769	967	-0.00310	[49]
716	911	717	968	769	967	774	900	-0.00310	[50]
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2240	350	2240	575	2450	575	2450	350	-0.00310	[224]
2240	575	2240	800	2450	800	2450	575	-0.00310	[225]
2450	575	2450	800	2660	800	2660	575	-0.00310	[226]
2450	350	2450	462	2555	462	2555	350	-0.00310	[227]
2450	462	2450	575	2555	575	2555	462	-0.00310	[228]
2555	462	2555	575	2660	575	2660	462	-0.00310	[229]
2555	350	2555	462	2660	462	2681	374	-0.00310	[230]
2240	800	2240	1250	2660	1250	2660	800	-0.00310	[231]
2240	1250	2240	1700	2660	1700	2660	1250	-0.00310	[232]
2660	1925	2240	1925	2240	2150	2660	2150	-0.00310	[233]
2660	1700	2240	1700	2240	1925	2660	1925	-0.00310	[234]
2240	2150	2240	2375	2450	2375	2450	2150	-0.00310	[235]
2240	2375	2240	2600	2450	2600	2450	2375	-0.00310	[236]
2450	2375	2450	2600	2660	2600	2660	2375	-0.00310	[237]
2450	2150	2450	2375	2660	2375	2660	2150	-0.00310	[238]
2240	2600	2240	2825	2450	2825	2450	2600	-0.00310	[239]
2240	2825	2239	2885	2314	2885	2345	2825	-0.00310	[240]
2345	2825	2314	2885	2449	2885	2450	2825	-0.00310	[241]
2450	2825	2449	2885	2540	2885	2555	2825	-0.00310	[242]
2555	2825	2540	2885	2659	2885	2660	2825	-0.00310	[243]
2450	2600	2450	2825	2660	2825	2660	2600	-0.00310	[244]
2238	3197	2449	3207	2449	3164	2239	3164	-0.00310	[245]
2449	3207	2660	3201	2636	3166	2449	3164	-0.00310	[246]
2681	374	2660	462	2765	462	2764	368	-0.00310	[247]
2660	462	2660	575	2765	575	2765	462	-0.00310	[248]
2765	462	2765	575	2870	575	2870	462	-0.00310	[249]
2764	368	2765	462	2870	462	2864	359	-0.00310	[250]
2660	575	2660	800	2870	800	2870	575	-0.00310	[251]
2870	575	2870	800	3005	798	3061	576	-0.00310	[252]

2864	359	2870	462	2975	462	2972	337	-0.00310	[253]
2870	462	2870	575	2975	575	2975	462	-0.00310	[254]
2975	462	2975	575	3061	576	3067	462	-0.00310	[255]
2972	337	2975	462	3067	462	3067	311	-0.00310	[256]
2660	800	2660	1025	2870	1025	2870	800	-0.00310	[257]
2660	1025	2660	1250	2870	1250	2870	1025	-0.00310	[258]
2870	1025	2870	1250	2973	1249	2985	1023	-0.00310	[259]
2870	800	2870	1025	2985	1023	3005	798	-0.00310	[260]
2660	1250	2660	1475	2870	1475	2870	1250	-0.00310	[261]
2660	1475	2660	1700	2870	1700	2870	1475	-0.00310	[262]
2870	1475	2870	1700	2970	1697	2970	1474	-0.00310	[263]
2870	1250	2870	1475	2970	1474	2973	1249	-0.00310	[264]
2660	1700	2660	1925	2870	1925	2870	1700	-0.00310	[265]
2660	1925	2660	2150	2870	2150	2870	1925	-0.00310	[266]
2870	1925	2870	2150	2987	2148	2985	1925	-0.00310	[267]
2870	1700	2870	1925	2985	1925	2970	1697	-0.00310	[268]
2660	2150	2660	2375	2870	2375	2870	2150	-0.00310	[269]
2660	2375	2660	2600	2870	2600	2870	2375	-0.00310	[270]
2870	2375	2870	2600	3031	2600	2977	2372	-0.00310	[271]
2870	2150	2870	2375	2977	2372	2987	2148	-0.00310	[272]
2660	2600	2660	2825	2870	2825	2870	2600	-0.00310	[273]
2660	2825	2659	2885	2688	2977	2765	2825	-0.00310	[274]
2688	2977	2720	3084	2944	3049	2907	2937	-0.00310	[275]
2765	2825	2688	2977	2907	2937	2870	2825	-0.00310	[276]
2870	2825	2944	3049	3023	2924	3087	2821	-0.00310	[277]
2870	2600	2870	2825	3087	2821	3031	2600	-0.00310	[278]
2636	3166	2660	3201	2714	3198	2714	3171	-0.00310	[279]
2714	3171	2714	3198	2855	3198	2899	3123	-0.00310	[280]
2720	3084	2714	3171	2899	3123	2944	3049	-0.00310	[281]

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 RET
RET
SWI
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*****************************************************************
*                                                               *
*           B A R R   E N G I N E E R I N G   C O .             *
*                                                               *
*     Single-Layer Analytic Element Method (SLAEM) Model        *
*                                                               *
*               File:  WCPPON_S.DAT                             *
*                                                               *
*       Element Type:  Areal Element Module                     *
*        Element Use:  Defines given strength areal elements    *
*                      that simulate industrial ponds.          *
*                                                               *
*               Date:  March 19, 1994                           *
*      Revision Date:                                           *
*                                                               *
*****************************************************************
 RET
ARE
 DRAW TOP
 GIVEN
  1991   1853   2044   1855   2055   1806   1992   1824   -0.04500   [P1-1]
  2044   1855   2097   1857   2118   1788   2055   1806   -0.04500   [P1-1]
  2055   1806   2118   1788   2140   1720   2066   1757   -0.04500   [P1-1]
  1992   1824   2055   1806   2066   1757   1993   1795   -0.04500   [P1-1]
  2097   1857   2143   1858   2164   1801   2118   1788   -0.04500   [P1-2]
  2143   1858   2189   1859   2211   1814   2164   1801   -0.04500   [P1-2]
  2164   1801   2211   1814   2233   1770   2186   1745   -0.04500   [P1-2]
  2118   1788   2164   1801   2186   1745   2140   1720   -0.04500   [P1-2]
  2140   1720   2186   1745   2187   1702   2150   1690   -0.04500   [P1-3]
  2186   1745   2233   1770   2224   1715   2187   1702   -0.04500   [P1-3]
  2187   1702   2224   1715   2215   1661   2188   1660   -0.04500   [P1-3]
  2150   1690   2187   1702   2188   1660   2161   1660   -0.04500   [P1-3]
  2161   1660   2188   1660   2177   1622   2145   1620   -0.04500   [P1-4]
  2188   1660   2215   1661   2209   1625   2177   1622   -0.04500   [P1-4]
  2177   1622   2209   1625   2204   1590   2167   1585   -0.04500   [P1-4]
  2145   1620   2177   1622   2167   1585   2130   1580   -0.04500   [P1-4]
  1949   1556   2039   1568   2041   1530   1975   1522   -0.04500   [P1-5]
  2039   1568   2130   1580   2107   1539   2041   1530   -0.04500   [P1-5]
  2041   1530   2107   1539   2085   1498   2043   1493   -0.04500   [P1-5]
  1975   1522   2041   1530   2043   1493   2002   1489   -0.04500   [P1-5]
  2130   1580   2167   1585   2153   1544   2107   1539   -0.04500   [P1-6]
  2167   1585   2204   1590   2200   1549   2153   1544   -0.04500   [P1-6]
  2153   1544   2200   1549   2196   1509   2140   1503   -0.04500   [P1-6]
  2107   1539   2153   1544   2140   1503   2085   1498   -0.04500   [P1-6]
  2174   1507   2196   1509   2188   1464   2168   1462   -0.04500   [P1-7]
  2168   1462   2188   1464   2180   1420   2163   1417   -0.04500   [P1-7]
  2163   1417   2180   1420   2172   1375   2158   1372   -0.04500   [P1-7]
  2158   1372   2172   1375   2165   1331   2153   1327   -0.04500   [P1-7]
  1952   1380   1961   1384   1966   1353   1946   1340   -0.20000   [P2-1]
  1961   1384   1970   1389   1987   1366   1966   1353   -0.20000   [P2-1]
  1966   1353   1987   1366   2004   1343   1972   1322   -0.20000   [P2-1]
  1946   1340   1966   1353   1972   1322   1940   1301   -0.20000   [P2-1]
  1940   1301   1972   1322   1989   1293   1965   1273   -0.20000   [P2-2]
  1972   1322   2004   1343   2013   1314   1989   1293   -0.20000   [P2-2]
  1989   1293   2013   1314   2022   1286   2006   1265   -0.20000   [P2-2]
  1965   1273   1989   1293   2006   1265   1991   1245   -0.20000   [P2-2]
  1942   1220   1966   1232   1958   1204   1940   1198   -0.20000   [P2-3]
  1966   1232   1991   1245   1975   1211   1958   1204   -0.20000   [P2-3]
  1958   1204   1975   1211   1960   1177   1949   1177   -0.20000   [P2-3]
  1940   1198   1958   1204   1949   1177   1939   1177   -0.20000   [P2-3]
  1939   1177   1949   1177   1941   1137   1934   1138   -0.20000   [P2-4]
  1949   1177   1960   1177   1949   1136   1941   1137   -0.20000   [P2-4]
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    1941  1137  1949  1136  1939  1096  1934  1097  -0.20000  [P2-4]
    1934  1138  1941  1137  1934  1097  1929  1099  -0.20000  [P2-4]
    2062  1184  2079  1188  2083  1158  2054  1152  -0.15000  [P3-1]
    2079  1188  2097  1192  2112  1165  2083  1158  -0.15000  [P3-1]
    2083  1158  2112  1165  2127  1138  2086  1129  -0.15000  [P3-1]
    2054  1152  2083  1158  2086  1129  2046  1121  -0.15000  [P3-1]
    2046  1121  2086  1129  2084  1101  2054  1096  -0.15000  [P3-2]
    2086  1129  2127  1138  2115  1106  2084  1101  -0.15000  [P3-2]
    2084  1101  2115  1106  2103  1074  2082  1072  -0.15000  [P3-2]
    2054  1096  2084  1101  2082  1072  2062  1071  -0.15000  [P3-2]
    1840   487  1907   497  1908   479  1844   470  -0.01000  [P4-3]
    1907   497  1974   508  1973   489  1908   479  -0.01000  [P4-3]
    1908   479  1973   489  1973   470  1910   462  -0.01000  [P4-3]
    1844   470  1908   479  1910   462  1848   454  -0.01000  [P4-3]
  RET
RET
SWI
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*****************************************************************
*                                                               *
*            B A R R   E N G I N E E R I N G   C O .            *
*                                                               *
*      Single-Layer Analytic Element Method (SLAEM) Model       *
*                                                               *
*             File:  WCPMONWL.MAP                               *
*                                                               *
*     Element Type:  Map Module                                 *
*      Element Use:  Defines map features for                   *
*                    monitoring wells.                          *
*                                                               *
*             Date:  March 19, 1994                             *
*    Revision Date:                                             *
*                                                               *
*****************************************************************
 RET
MAP
 PLOT ON
 POINT
  2254.3  1838.9 * P-102
  1710.9   856.3 * P-103
  1851.7  1381.2 * P-104
  2444.8   811.5 * P-105
  1533.4  1390.6 * P-107
  2760.6  3169.5 * W-2A/2B/2C
  1490.8  3181.7 * W-4A/4B/4C
   976.4  3232.0 * W-5
   947.4  2813.2 * W-6
  2601.4  2722.4 * W-12
  2553.6  2580.3 * W-13
  1614.2  1278.5 * MW-1S/1D
  1835.8  1840.9 * MW-3S/3D
  2159.8   983.5 * MW-4S/4D
  1103.4   673.4 * MW-5S/5D
  1205.0  1301.3 * MW-6S/6D
  2183.9  1418.1 * MW-7S/7D
  2176.5   452.3 * MW-8S/8D
  1977.3  1094.6 * MW-9S/9D
  1334.2  1881.8 * MW-11S/11D
  1510.3   566.3 * MW-10S/10D
  2560.6   846.1 * MW-12S/12D
  2567.4  1256.7 * MW-13S/13D
  2507.6  1801.8 * MW-14S/14D
  1827.1  2065.1 * MW-15S/15D
 RET
RET
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Appendix 6-A

Identification of Phase II Analytical Parameters for Soil and Groundwater

APPENDIX 6-A

IDENTIFICATION OF PHASE II ANALYTICAL PARAMETERS FOR SOIL AND GROUNDWATER

This appendix describes the method used to select the Phase II analytical parameters for soil and groundwater from the more extended list of Phase I parameters. This method was originally presented in Sections 2.4.4.4 and 2.4.5.3 of the July 1993 Phase I Technical Memorandum (Barr, 1993b).

IDENTIFICATION OF PHASE II ANALYTICAL PARAMETERS FOR SOIL

Table 6-A-1 identifies the Phase II analytical parameters that were used to characterize the nature and extent of chemical parameters in the soils on-site. These parameters were chosen from the more extended list of Phase I parameters. The selection of these parameters is discussed below.

The following rationale was used to select the Phase II soil analytical parameters from the more extended list of Phase I parameters:

1. Parameters that were not detected or not detected above the maximum U.S. EPA-designated background concentrations in Table 6-A-2 were removed from the list. This procedure eliminated the following parameters: silver; all volatile organic compounds except methylene chloride, acetone, carbon disulfide, 1,1-dichloroethane, 1,2-dichloroethylene, chloroform, methyl ethyl ketone, 1,1,1-trichloroethane, trichloroethylene, 2-hexanone, styrene, benzene, ethyl benzene, toluene, and xylenes; all phenolic compounds except phenol, o-cresol, p-cresol, 2,4-dimethylphenol; all pesticides; and all PCBs.

2. Parameters not detected at concentrations exceeding the lowest of the upper-range concentrations for naturally occurring soils (Table 6-A-3) were removed from the list. This procedure eliminated the following parameters: aluminum, barium, beryllium, cadmium,

calcium, chromium, cobalt, copper, iron, lead, nickel, sodium, thallium, vanadium, and zinc.

3. Parameters that were detected only once or detected above naturally occurring background ranges only once were removed from the list. These parameters were: antimony, magnesium, 1,1-dichloroethane, 1,2-dichloroethylene, 2-hexanone, and pentachlorophenol. 1,1-Dichloroethane and 1,2-dichloroethylene are not associated with manufactured gas plant/coking or creosote operations. Pentachlorophenol came into use as a wood-treating product during the 1930s (Wilkinson, 1979) and, therefore, would not have been used at the former CT&T wood-treating facility which operated from approximately 1908 to 1912.

4. Parameters that are not associated with manufactured gas plant/coking or creosote operations and that were detected infrequently (10 percent of samples or less) and at low concentrations (less than 20 µg/kg) were also removed from the list (Table 6-A-4). These parameters were chloroform, 1,1,1-trichloroethane, and trichloroethylene.

5. Parameters that are common laboratory contaminants (U.S. EPA, 1988) and/or are not associated with manufactured gas plant/coking and creosoting operations were removed from the list. These parameters were methylene chloride, acetone, methyl ethyl ketone, and bis(2-ethylhexyl) phthalate.

6. Two parameters were removed from the list because of their lack of typical association with manufactured gas plant/coking and creosoting operations, their association with detected BETX compounds, and their less frequent detection at lower concentrations (relative to BETX compounds). The two compounds removed on this basis are styrene and carbon disulfide.

7. One parameter, 4-nitrophenol, was removed from the list because it was detected less frequently than the other phenolic compounds and

because toxicity/health-effect data are not available for this parameter.

Those parameters remaining on the list for the Phase II investigation area shown in Table 6-A-1. Cadmium and lead were retained on the list to provide soil quality data for correlation with groundwater quality data collected for these parameters.

IDENTIFICATION OF PHASE II ANALYTICAL PARAMETERS FOR GROUNDWATER

The first round of groundwater samples collected from monitoring wells installed in Phase II were analyzed for the full-scan parameter list to establish an initial groundwater quality characterization. The second round of Phase II groundwater samples, collected from all the site monitoring wells, were analyzed for the chemical parameters listed below:

- Phenolic compounds (see soil parameter list in Table 6-A-1);
- PAH compounds (see soil parameter list in Table 6-A-1);
- Volatile organic compounds (VOCs) (see list in Table 6-A-5);
- Arsenic (total, +III, +V);
- Cyanide, total and weak acid dissociable (corrected for sulfide interferences);
- Thiocyanate;
- Cadmium;
- Lead;
- Mercury;
- Selenium; and
- Total ammonia.

Cadmium was selected for Phase II groundwater analyses due to its apparent association with elevated concentrations of other manufactured gas plant/coking and creosote compounds, and because cadmium concentrations exceeded the corresponding MCL at several sampling locations. Selenium was included to provide groundwater quality data for correlation with soil quality data collected for this parameter, and because two groundwater samples showed selenium concentrations exceeding the corresponding IWQS. Mercury was included to provide groundwater quality data for correlation with soil quality data collected for this parameter.

Total ammonia was included in Phase II groundwater analyses due to its typical association with manufactured gas plant/coking by-products and residuals and its identification as a "pollutant of concern" in the Remedial Action Plan for the Waukegan Area of Concern (Hey and Associates, Inc., 1992).

Iron and manganese were not included in the analytical parameter list for the second round of Phase II because the Secondary MCLs for these parameters are not enforceable standards.

REFERENCES

Barr Engineering Co. 1993b. Remedial Investigation/Feasibility Study, Phase I Technical Memorandum, Waukegan Manufactured Gas and Coke Plant Site, Waukegan, Illinois. Prepared for North Shore Gas Company.

Bowen, H.J.M. 1966. Trace Elements in Biochemistry. Academic Press, New York.

Dragun, J. 1988. The Soil Chemistry of Hazardous Materials. Hazardous Materials Control Research Institute, Maryland.

Hey and Associates, Inc. 1992. Draft Waukegan Area of Concern Remedial Action Plan. Prepared for Illinois Environmental Protection Agency, Springfield, Illinois.

Shacklette, H. and J.G. Boerngen. 1984. Element Concentrations in Soils and Other Surficial Materials of the Conterminous United Sates. U.S. Geological Survey Professional Paper 1270. United States Government Printing Office, Washington.

U.S. EPA. February 1988. Laboratory Data Validation Functional Guidelines for Organics Analyses.

Wilkinson, J.G. 1979. Industrial Timber Preservation. Associated Business Press, London, England.

TABLE 6-A-1

PHASE II ANALYTICAL PARAMETERS - SOIL QUALITY
(Chemical Parameters)

INORGANICS	VOLATILE ORGANIC COMPOUNDS[1]	POLYNUCLEAR AROMATIC HYDROCARBONS[1]	PHENOLIC COMPOUNDS[1]
Arsenic Cadmium Lead Mercury Selenium Cyanide	Benzene Ethyl benzene Toluene Xylenes	Naphthalene 2-Methylnaphthalene Acenaphthylene Acenaphthene Dibenzofuran Fluorene Phenanthrene Anthracene Fluoranthene Pyrene Benzo(a)anthracene Chrysene Benzo(b+k)fluoranthene Benzo(a)pyrene Indeno(1,2,3-cd)pyrene Dibenzo(a,h)anthracene Benzo(g,h,i)perylene Carbazole	Phenol o-Cresol p-Cresol 2,4-Dimethylphenol

[1] The laboratory will indicate when criteria were not met for estimating concentrations below the quantitation limit.

TABLE 6-A-2

BACKGROUND SOIL SAMPLE
CONCENTRATION RANGES

	U.S. EPA-DESIGNATED BACKGROUND SAMPLES (BS01, BS02 & BS04)	FINAL WORK PLAN BACKGROUND SAMPLES (BS01-BS08)
INORGANICS (concentrations in mg/kg)		
Aluminum	1,520 - 1,930	881 - 4,560
Antimony	<2.3	<2.3 - 5.8
Arsenic	1.7 - 2	<0.76 - 235
Barium	6.4 - 22.2	5.1 - 232
Beryllium	<0.17	<0.12 - 0.4
Cadmium	<0.62	<0.61 - 7.3
Calcium	16,200 - 31,900	16,200 - 36,100
Chromium, total	<5.3 - 18.1	<5.1 - 231
Cobalt	1.8 - 2.4	1.6 - 7.3
Copper	4.3 - 7.1	3.9 - 160
Iron	3,710 - 4,330	2,560 - 39,700
Lead	3.6 - 9.2	3.4 - 434
Magnesium	7,670 - 16,200	7,670 - 17,300
Manganese	78.6 - 163	78.6 - 357
Mercury	<0.08	<0.07 - 1.7
Nickel	3.2 - 4.8	2.6 - 33.3
Potassium	278 - 403	<151 - 680
Selenium	<0.27	<0.27 - 0.93
Silver	<0.36 - 0.71	<0.36 - 5.4
Sodium	<339	<447
Thallium	<0.23	<0.40
Vanadium	5.6 - 8	4.4 - 14.9
Zinc	19.2 - 27.6	17.6 - 764
Cyanide	<0.19	<0.19 - 1.2
VOLATILE ORGANIC COMPOUNDS (concentrations in µg/kg)		
Chloromethane	<11	<13
Bromomethane	<11	<13
Vinyl chloride	<11	<13
Chloroethane	<11	<13
Methylene chloride	<32	<51
Acetone	<23	<51

TABLE 6-A-2 (Cont.)

BACKGROUND SOIL SAMPLE
CONCENTRATION RANGES

	U.S. EPA-DESIGNATED BACKGROUND SAMPLES (BS01, BS02 & BS04)	FINAL WORK PLAN BACKGROUND SAMPLES (BS01-BS08)
Carbon disulfide	<11	<12
1,1-Dichloroethylene	<11	<13
1,1-Dichloroethane	<11	<13
1,2-Dichloroethylene	<11	<13
Chloroform	<11	<12
1,2-Dichloroethane	<11	<13
Methyl ethyl ketone	<11	<11 - 20
1,1,1-Trichloroethane	<11	<13
Carbon tetrachloride	<11	<13
Bromodichloromethane	<11	<13
1,2-Dichloropropane	<11	<13
cis-1,3-Dichloro-1-propene	<11	<13
Trichloroethylene	<11	<12
Chlorodibromomethane	<11	<13
1,1,2-Trichloroethane	<11	<13
trans-1,3-Dichloro-1-propene	<11	<13
Bromoform	<11	<13
Methyl isobutyl ketone	<11	<13
2-Hexanone	<11	<13
Tetrachloroethylene	<11	<13
1,1,2,2-Tetrachloroethane	<11	<13
Chlorobenzene	<11	<13
Styrene	<11	<13
Benzene	<11	<13
Ethyl benzene	<11	<13
Toluene	<11	<12
Xylenes	<11	<12
PROJECT SPECIFIC PAH COMPOUNDS (concentrations in µg/kg)		
Naphthalene	<350	<400
2-Methylnaphthalene	<350	<400
Acenaphthylene	<350	<350 - 590

TABLE 6-A-2 (Cont.)

BACKGROUND SOIL SAMPLE
CONCENTRATION RANGES

	U.S. EPA-DESIGNATED BACKGROUND SAMPLES (BS01, BS02 & BS04)	FINAL WORK PLAN BACKGROUND SAMPLES (BS01-BS08)
Acenaphthene	<350	<400
Dibenzofuran	<350	<400
Fluorene	<350	<400
Phenanthrene	<350	68 - 1,300
Anthracene	<350	<350 - 560
Fluoranthene	<350	47 - 2,400
Pyrene	<350	35 - 2,600
Benzo(g,h,i)perylene	<350	89 - 810
Benzo(a)anthracene	<350	40 - 1,600
Benzo(b)fluoranthene	<350	42 - 2,000
Benzo(k)fluoranthene	<350	46 - 1,100
Benzo(a)pyrene	<350	46 - 1,400
Chrysene	<350	40 - 1,700
Dibenzo(a,h)anthracene	<350	<350 - 440
Indeno(1,2,3-cd)pyrene	<350	40 - 1,100
PHENOLIC COMPOUNDS (concentrations in µg/kg)		
Phenol	<350	<450
2-Chlorophenol	<350	<450
o-Cresol	<350	<450
p-Cresol	<350	<450
2-Nitrophenol	<350	<450
2,4-Dimethylphenol	<350	<450
4-Chloro-3-methylphenol	<350	<450
2,4,6-Trichlorophenol	<350	<450
2,4,5-Trichlorophenol	<840	<1,100
2,4-Dinitrophenol	<840	<1,100
4-Nitrophenol	<840	<1,100
2-Methyl-4,6-dinitrophenol	<840	<1,100
Pentachlorophenol	<840	<1,100

TABLE 6-A-2 (Cont.)

BACKGROUND SOIL SAMPLE
CONCENTRATION RANGES

	U.S. EPA-DESIGNATED BACKGROUND SAMPLES (BS01, BS02 & BS04)	FINAL WORK PLAN BACKGROUND SAMPLES (BS01-BS08)
OTHER SEMIVOLATILE COMPOUNDS (concentrations in µg/kg)		
Bis(2-chloroethyl)ether	<350	<450
1,3-Dichlorobenzene	<350	<450
1,4-Dichlorobenzene	<350	<450
1,2-Dichlorobenzene	<350	<450
Bis(2-chloroisopropyl)ether	<350	<450
N-Nitrosodi-n-propylamine	<350	<450
Hexachloroethane	<350	<450
Nitrobenzene	<350	<450
Isophorone	<350	<450
Bis(2-chloroethoxy)methane	<350	<450
1,2,4-Trichlorobenzene	<350	<450
4-Chloroaniline	<350	<450
Hexachlorobutadiene	<350	<450
Hexachlorocyclopentadiene	<350	<450
2-Chloronaphthalene	<350	<450
2-Nitroaniline	<850	<1,100
Dimethyl phthalate	<350	<450
2,6-Dinitrotoluene	<350	<450
3-Nitroaniline	<850	<1,100
2,4-Dinitrotoluene	<350	<450
Diethyl phthalate	<350	<450
4-Chlorophenyl phenyl ether	<350	<450
4-Nitroaniline	<850	<1,100
N-Nitrosodiphenylamine	<350	<450
4-Bromophenyl phenyl ether	<350	<450
Hexachlorobenzene	<350	<450
Di-n-butyl phthalate	<350	<450
Butyl benzyl phthalate	<350	<450
3,3-Dichlorobenzidine	<350	<450
Bis(2-ethylhexyl)phthalate	<420	<350 - 4,500

TABLE 6-A-2 (Cont.)

BACKGROUND SOIL SAMPLE
CONCENTRATION RANGES

	U.S. EPA-DESIGNATED BACKGROUND SAMPLES (BS01, BS02 & BS04)	FINAL WORK PLAN BACKGROUND SAMPLES (BS01-BS08)
Di-n-octyl phthalate	<350	<450
Carbazole	<350	<400
2,4-Dichlorophenol	<350	<450
a-BHC	<7.2	<120
b-BHC	<7.2	<120
d-BHC	<7.2	<120
g-BHC (Lindane)	<7.2	<120
Heptachlor	<7.2	<120
Aldrin	<7.2	<120
Heptachlor epoxide	<7.2	<120
Endosulfan I	<7.2	<120
Dieldrin	<14	<230
4,4'-DDE	<14	<230
Endrin	<14	<230
Endosulfan II	<14	<230
4,4'-DDD	<14	<230
Endosulfan sulfate	<14	<230
4,4'-DDT	<14	<230
Methyloxyclor	<72	<1,200
Endrin ketone	<14	<230
Endrin aldehyde	<14	<230
cis-Chlordane	<7.2	<120
trans-Chlordane	<7.2	<120
Toxaphene	<720	<12,000
PCB-1016	<140	<2,300
PCB-1221	<280	<4,600
PCB-1232	<140	<2,300
PCB-1242	<140	<2,300
PCB-1248	<35 - 1,500	<35 - 23,000
PCB-1254	<140	<2,300
PCB-1260	<35 - 69	<35 - 850

TABLE 6-A-3

SOIL QUALITY
NATURALLY OCCURRING CONCENTRATIONS OF INORGANICS

PARAMETER	NATURAL COMPOSITION OF SOILS (mg/kg)			
	BOWEN, 1966	SHACKLETTE & BOERNGEN, 1984	DRAGUN, 1988	REPRESENTATIVE UPPER RANGE CONCENTRATION[1]
Aluminum	10,000-300,000	700-<100,000	10,000-300,000	100,000
Antimony	--	<1-8.8	0.6-10	8.8
Arsenic	0.1-40	<0.1-97	1.0-40	40
Barium	100-3,000	10-5,000	100-3,500	3,000
Beryllium	0.1-40	<1-15	0.1-40	15
Cadmium	0.01-0.7	--	0.01-7.0	7.0[2]
Calcium	7,000-500,000	100-320,000	100-400,000	320,000
Chromium, total	5-3,000	1-2,000	5.0-3,000	2,000
Cobalt	1-40	<3-70	1.0-40	40
Copper	2-100	<1-700	2.0-100	100
Iron	7,000-550,000	100->100,000	7,000-550,000	100,000
Lead	2-200	<10-700	2.0-200	200
Magnesium	600-6,000	50->100,000	600-6,000	6,000
Manganese	100-4,000	<2-7,000	100-4,000	4,000
Mercury	0.01-0.3	<0.01-4.6	0.01-0.08	0.3[2]
Nickel	10-1,000	<5-700	5.0-1,000	700
Potassium	400-30,000	50-63,000	400-30,000	30,000
Selenium	0.01-2	<0.1-4.3	0.1-2.0	2.0
Silver	0.01-5	--	0.1-5.0	5.0
Sodium	750-7,500	<500-100,000	750-7,500	7,500
Thallium	0.1-12	2.2-31	0.1-12	12
Vanadium	20-500	<7-500	20-500	500
Zinc	10-300	<5-2,900	10-300	300
Cyanide	--	--	--	--

[1] The lowest of the upper range concentrations was chosen to be the representative upper range concentration.
[2] Selected value is the lowest value that exceeds method detection limits for analyzed soil samples.

TABLE 6-A-4

MAXIMUM VOLATILE ORGANIC COMPOUND CONCENTRATIONS[1]
SOIL QUALITY

PARAMETER	FREQUENCY OF DETECTION[2] (Maximum Concentration in µg/kg)			
	BS	TT&SC	SS	SB
Methylene Chloride	3/9 (4)	6/29 (4,500)	2/18 (120)	1/3 (19)
Acetone	ND	5/29 (150)	1/18 (29)	3/3 (170)
Carbon disulfide	ND	17/29 (640)	8/18 (7)	2/3 (4)
1,1-Dichloroethane	ND	1/29 (1)	ND	ND
1,2-Dichloroethylene	ND	1/29 (4)	ND	ND
Chloroform	ND	4/29 (13)	2/18 (4)	ND
Methyl Ethyl Ketone	2/9 (20)	13/29 (64)	5/18 (13)	2/3 (37)
1,1,1-Trichloroethane	ND	1/29 (6)	1/18 (6)	ND
Trichloroethylene	1/9 (2)	1/29 (2)	1/18 (1)	ND
2-Hexanone	ND	ND	ND	1/3 (3)
Styrene	ND	3/29 (62,000)	1/18 (5)	ND

1 Excluding benzene, toluene, xylenes, and ethyl benzene.
2 Entries show the number of samples in which the parameter was detected over the total number of samples analyzed for the parameter. The number in parentheses is the maximum concentration detected.

BS Background Soil Sample.
TT&SC Potential Source Area Investigation Sample.
SS Surficial Soil Sample.
SB Pilot Boring Soil Sample.
ND Not detected.

TABLE 6-A-5

PHASE II ANALYTICAL PARAMETERS FOR GROUNDWATER

Polynuclear Aromatic Hydrocarbons

Naphthalene
2-Methylnaphthalene
Acenaphthylene
Acenaphthene
Dibenzofuran
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benzo(a)anthracene
Chrysene
Benzo(b)fluoranthene
Benzo(k)fluoranthene
Benzo(a)pyrene
Indeno(1,2,3-cd)pyrene
Dibenzo(a,h)anthracene
Benzo(g,h,i)perylene
Carbazole

Phenolic Compounds

Phenol
o-Cresol
p-Cresol
2,4-Dimethylphenol

Inorganics

Arsenic (total, +III, +V)
Cadmium
Lead
Mercury
Selenium
Total ammonia
Total cyanide
Thiocyanate
Weak and dissociable cyanide
Amenable cyanide

Volatile Organic Compounds

Chloromethane
Bromomethane
Vinyl chloride
Chloroethane
Methylene chloride
Acetone
Carbon disulfide
1,1-Dichloroethylene
1,1-Dichloroethane
1,2-Dichloroethylene
Chloroform
1,2-Dichloroethane
Methyl ethyl ketone
1,1,1-Trichloroethane
Carbon tetrachloride
Bromodichloromethane
1,2-Dichloropropane
cis-1,3-Dichloro-1-propene
Trichloroethylene
Chlorodibromomethane
1,1,2-Trichloroethane
trans-1,3-Dichloro-1-propene
Bromoform
Methyl isobutyl ketone
2-Hexanone
Tetrachloroethylene
1,1,2,2-Tetrachloroethane
Chlorobenzene
Styrene
Benzene
Ethyl benzene
Toluene
Xylenes

Appendix 7-A

Statistical Procedures Used in the Evaluation of Background Soil Samples

APPENDIX 7-A
STATISTICAL PROCEDURES USED IN THE EVALUATION OF BACKGROUND SOIL SAMPLES

Representative upper range background concentrations for key site parameters were calculated with the one-sided upper tolerance limit approach. The type of statistical procedure used to calculate the tolerance limit is dependent on the percentage of background sample data reported to be below the limit of detection (LOD). The key site parameters are grouped into one of the following categories for the purpose of selecting the applicable statistical procedure:

- Category I - Concentrations detected in all background samples (no observations in the background data below the LOD).
- Category II - Concentrations with at least one but less than 15% of the observations in the background data below the LOD.
- Category III - Concentrations with greater than 15% and less than 50% of the observations in the background data below the LOD.
- Category IV - Concentrations with greater than 50% and less than 100% of the observations in the background below the LOD.

For concentrations that were not detected in any background sample, such as ethyl benzene, there is no appropriate statistical procedure that can be applied to estimate the upper range background concentration.

The mean and standard deviation are computed for each Category I, II, and III parameters using appropriate statistical procedures. Means and standard deviations cannot be computed for parameters in Category IV. Once the mean and standard deviation are computed, the representative upper range background concentration can be determined by calculating the one-sided upper tolerance limit using the following equation:

Representative Upper Range Background Concentration
= Upper Tolerance Limit
= (mean) + K x (Standard Deviation)

where K is the one-sided normal tolerance factor. The purpose of the upper tolerance limit approach is to determine the representative upper range concentration, below which a specified percentage of the sample population of nonimpacted soil samples will fall with a specified degree of confidence. The

K value for 11 sample observations, a population coverage of 95 percent, and a confidence of 95 percent is 2.815 (U.S. EPA, 1989b). The category of and statistical method applied to each key site parameter are summarized as follows:

Arsenic:

- Category: II (9% of data below the LOD)
- Data Distribution: Lognormal
- Analysis Method: Minimum variance unbiased (MVU) estimators (see Gilbert, 1987) values below the LOD are replaced with a value of 1/2 the detection limit
- Mean: 9.9 mg/kg Standard Deviation: 10.7 mg/kg
- Upper range background concentration: 40 mg/kg

Cyanide (Total):

- Category: IV (91% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 0.22 mg/kg as the representative LOD
- Mean: NA Standard Deviation: NA
- Upper range background concentration: 1.5 mg/kg

Cadmium:

- Category: IV (64% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 0.7 mg/kg as the representative LOD
- Mean: NA Standard Deviation: NA
- Upper range background concentration: 4.2 mg/kg

Lead:

- Category: I (none of data below the LOD)
- Data Distribution: Lognormal
- Analysis Method: MVU estimators (see Gilbert, 1987)
- Mean: 25.9 mg/kg Standard Deviation: 30.0 mg/kg
- Upper range background concentration: 110 mg/kg

Mercury:

- Category: IV (82% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 0.08 mg/kg as the representative LOD
- Mean: NA Standard Deviation: NA
- Upper range background concentration: 1.5 mg/kg

Selenium:

- Category: IV (82% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 0.32 mg/kg as the representative LOD
- Mean: NA Standard Deviation: NA
- Upper range background concentration: 1.7 mg/kg

Benzene:

- Category: IV (91% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 1.1 µg/kg as the representative LOD
- Mean: NA Standard Deviation: NA
- Upper range background concentration: 2.6 µg/kg

Ethyl Benzene:

- All data reported to be below the LOD
- There is no appropriate statistical procedure that can be applied to estimate the upper range background concentration

Toluene:

- Category: IV (64% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 1.1 µg/kg as the representative LOD
- Mean: NA Standard Deviation: NA

- Upper range background concentration: 3.2 µg/kg

Xylene:

- Category: IV (55% of data below the LOD)
- Data Distribution: NA
- Analysis Method: Poisson model (U.S. EPA, 1989b) used 1.1 µg/kg as the representative LOD
- Mean: NA Standard Deviation: NA
- Upper range background concentration: 5.0 µg/kg

Sum of BETX:

- Category: III (36% of data below the LOD)
- Data Distribution: Lognormal
- Analysis Method: Aitchison's Adjustment (U.S. EPA, 1989b)
- Mean: 2.0 µg/kg Standard Deviation: 2.9 µg/kg
- Upper range background concentration: 10.2 µg/kg

Total PAHs:

- Category: III (36% of data below the LOD)
- Data Distribution: Lognormal
- Analysis Method: Aitchison's Adjustment (U.S. EPA, 1989b)
- Mean: 2.1 µg/kg Standard Deviation: 5.5 µg/kg
- Upper range background concentration: 17.6 µg/kg

Carcinogenic PAHs:

- Category: III (46% of data below the LOD)
- Data Distribution: Lognormal
- Analysis Method: Aitchison's Adjustment (U.S. EPA, 1989b)
- Mean: 1.1 µg/kg Standard Deviation: 2.8 µg/kg
- Upper range background concentration: 9.1 µg/kg

Appendix 8-A

Mass Loading Calculations for Groundwater Discharges to Surface Waters

APPENDIX 8-A

MASS LOADING CALCULATIONS FOR GROUNDWATER DISCHARGES TO SURFACE WATERS

INTRODUCTION

The mass of chemicals in groundwater that could potentially discharge into Lake Michigan and Waukegan Harbor was estimated using a mass balance approach. The mass balance calculations were performed for benzene, phenol, arsenic, cyanide, and ammonia. These chemicals were selected because they are representative of groups of chemicals that are detected at relatively high concentrations, and because of their mobility in groundwater (compared to other site chemicals such as PAHs) and/or their toxicity and regulatory concentrations of concern. A detailed description of the approach and assumptions and a summary of the results of the calculations are provided below.

DESCRIPTION OF THE MASS BALANCE APPROACH

General Approach

The rates at which benzene, phenol, arsenic, cyanide, and ammonia potentially discharge to Waukegan Harbor and Lake Michigan were computed by:

- First, calculating estimates of flux rates across aquifer cross sections located near monitoring wells where chemical concentrations were measured. These sections were selected so that they are perpendicular to groundwater flow directions and intersect flow paths to either Waukegan Harbor or to Lake Michigan (Figure 8-A-1).

- Second, by reducing the estimated flux rates to account for degradation for those compounds that are expected to degrade (i.e., phenol and benzene) during transport from cross sections that are remote from the discharge zones.

The following sections describe each component of the method and the associated assumptions.

Identified Sections for Flux Computations

The sections were selected based on flow paths derived from the September 29, 1993 groundwater contour map. The sections are depicted on Figure 8-A-1. Sections AB, BC, and CD are located along the Slip No. 4. Section DE is located along Waukegan Harbor, east of the site. Section EF is located along a groundwater flow path, resulting in no flux of chemicals through that section. Section FG is located along the southern boundary of the site and intercepts groundwater that flows to the south toward Waukegan Harbor. This section is located approximately 1,100 feet from the harbor. Section GH is west of the site, approximately 350 feet from Lake Michigan. Section GH intercepts all groundwater flow paths toward the lake.

Horizontal and Vertical Distributions of Chemical Concentrations

The horizontal distributions of chemical concentrations along the sections were derived from the concentrations measured in December 1993 groundwater samples from shallow and deep monitoring wells. These distributions were constructed by projecting measured and interpolated concentrations onto the sections. The horizontal distributions were then used to compute horizontally averaged concentrations for the upper and lower aquifer portions of each section. These averaged concentrations were in turn used to compute mass loading rates to Waukegan Harbor and to Lake Michigan, in accordance with the method described in the following section.

The measured vertical distribution of chemicals was incorporated by assigning a representative value of 32 percent of the total aquifer saturated thickness for groundwater quality data from the deep portion of the sand aquifer. Groundwater quality data from the water table monitoring wells were assigned to 68 percent of the total aquifer saturated thickness. This distribution is consistent with the rationale for the division of the sand aquifer into two portions at a depth of approximately 21.5 feet. The rationale was discussed in Section 7.7.

Flux of Chemicals through the Sections

The flux of chemicals flowing through the sections was computed as the product of the horizontally averaged concentrations and the estimated total groundwater discharges through the upper and lower portions of each section.

The groundwater discharge to Slip No. 4 is controlled not only by the hydraulic head in the aquifer, but also by the water elevation in the slip and the resistance to flow (i.e., ratio of thickness and hydraulic conductivity) across the slurry wall. These factors were readily accounted for in the groundwater flow model developed for the WCP site (Appendix 5-C). The results from the SLAEM model were thus used to estimate groundwater discharges through Sections AB, BC, and CD. Groundwater discharges through Sections DE, FG, and GH were estimated based on observed groundwater elevations (and associated hydraulic gradients) and measured hydraulic conductivity values. The flow calculations were based on the Darcy equation, a hydraulic conductivity value of 30 feet/day, and average hydraulic gradients (0.0021 feet/foot across Section DE, 0.0006 feet/foot across Section FG, and 0.0026 feet/foot across Section GH). The cross-sectional flow areas were computed from the length of the sections and the saturated thicknesses observed for wells located near the sections.

Degradation of Phenol and Benzene

For Sections FG and GH that are located at distance upgradient of the corresponding discharge points, phenol and benzene were assumed to be exposed to degradation processes. This assumption is consistent with observed decreases in benzene and phenol concentrations with distance from Well MW-13D to the temporary well point sampling location at Boring SB-51. A first-order kinetic degradation model was used to estimate the fraction (F) of flux remaining at the discharge zone using:

$$F = \exp(-t_c . Ln(2)/t_{1/2})$$

where: $t_{1/2}$ is the chemical degradation half-life of the chemical, and t_c is the chemical travel time computed from the groundwater travel time t_{gw} using:

$$t_c = t_{gw} . R_d$$

where: the retardation factor R_d is related to the soil bulk density, the organic carbon partition coefficient K_{oc}, and the organic carbon content of the soil f_{oc} by:

$$R_d = 1 + \frac{\rho \, K_{oc} \, f_{oc}}{n}$$

An average organic carbon content f_{oc} of 2 percent was used to derive the retardation factor (Section 8.1.2), based on f_{oc} values reported for soil samples from the site (Section 8.1.2). In the area of the aquifer to which soil-water partitioning theory using the distribution coefficient approach is applied in this analysis, namely the deep and shallow portions of the aquifer downgradient of the site, the concentrations of benzene and phenol are more or less similar to each other. Soil-water partitioning theory for benzene is likely not valid in the deep portion of the aquifer in the center of the site because the concentrations of phenol are 100 to 500 times greater than those of benzene and competitive adsorption processes (Luft, 1984) would be expected to reduce benzene adsorption relative to distribution coefficient calculations.

The above approach assumes that observed reductions in organic parameter concentrations with distance are due to degradation. This assumption is reasonable for the objectives of the calculations, since; (1) dilution is not expected to be significant because the vast majority of contaminant mass in groundwater is in the deep zone and, thus, would not be significantly affected by mixing with infiltration; and (2) the examined flow path (Well MW-13D to Boring SB-51) is apparently along the center line of a migration plume, thus minimizing dispersion effects.

Half-lives for phenol and benzene were computed by adjusting the first-order kinetic degradation model (i.e., a rough calibration process) based on observed concentrations in groundwater samples from Monitoring Well MW-13D and Soil Boring SB-51 (Attachment 8-A-1). This method yielded half-lives of 3.8 years and 1.6 years for benzene and phenol, respectively. These half-life values are significantly greater than typical literature values (Table 6.2-1), indicating relatively low degradation rates. This may be due to smaller amounts of oxygen that would be available in the deeper portion of the aquifer (where the bulk of the contamination occurs) compared to shallower groundwater zones. The "calibrated" half-life for benzene is larger than the highest range of half-lives (i.e., lowest range of degradation rate) identified in the literature for degradation of benzene in groundwater (2 years under anaerobic conditions; Howard, et al., 1991). The "calibrated" half-life for phenol is larger (i.e., slower degradation rate) than the ranges identified in the literature. Thus, the degradation rates employed in this analysis are conservative.

REPRESENTATIVE ESTIMATED DISCHARGES OF PARAMETERS TO WAUKEGAN HARBOR AND LAKE MICHIGAN

The potential mass flux of chemicals discharging to Waukegan Harbor is summarized in Table 8-A-1. The detailed mass loading computations are presented in Attachment 8-A-1. The representative mass loading rates to Lake Michigan were computed to be approximately

160 grams/day of arsenic, 9 grams/day of cyanide, and 42 kg of ammonia per day. The calculations suggest that benzene and phenol would largely degrade during transport toward Lake Michigan.

The representative loadings of chemicals discharging to Waukegan Harbor were computed to be approximately 20 grams/day of benzene, 1,700 g/day of phenol, 120 grams/day of arsenic, 180 grams/day of cyanide, and 40 kg of ammonia per day.

SENSITIVITY ANALYSIS

Introduction

The mass loading computations developed for the Waukegan Harbor and Michigan Lake were analyzed for sensitivity to the variation in four parameters. These parameters are:

- Dilution,
- Total organic carbon content,
- Groundwater discharge rates, and
- Vertical distribution of contamination.

The sensitivity of the mass loading computations to these parameters was performed by systematically changing one parameter value at a time. The resulting mass loading rates to Waukegan Harbor and Michigan Lake were then compared to those computed for the representative case presented in Table 8-A-1. Sensitivity analysis results are presented in Tables 8-A-2 and 8-A-3.

The following sections describes the procedure and the results of the sensitivity analysis to each of the parameters varied.

Sensitivity to Dilution Effect

Dilution was not accounted for in the representative case mass loading computations. In the representative case, it was assumed that the reduction in concentration from the concentration observed near Section GH to that observed near SB-51 was caused essentially by biodegradation. If a portion of this reduction is attributed to dilution, the calibrated biodegradation rates would be smaller and mass loading rates would increase. Because dilution affects only the estimates of half-lives, accounting for dilution will affect the mass loading computations only for non-conservative parameters (i.e., benzene and phenol) and solely for those sections for which degradation along the travel path was assumed (i.e., Sections FG and GH).

The effect of dilution was estimated by comparing concentration observed near Section GH and near SB-51 and SB-52 for a conservative parameter, in this case cyanide. Assuming the reduction in average cyanide concentration is due only to dilution, a dilution factor of 1.5 is computed. This factor was used to estimate the concentrations of benzene and phenol at SB-51 prior to dilution. Half-lives were then calibrated to these estimated concentrations. The results are presented in Table 1 of Attachment 8-A-1. Accounting for dilution resulted in an increase of benzene calibrated half-life from 3.8 years to 4.4 years, and in an increase of phenol half-life from 1.55 years to 1.68 years. These increased half-lives, however, did not significantly affect the mass loading rates of benzene and phenol to Michigan Lake (Table 8-A-3).

Sensitivity to Change in Total Organic Carbon Content

Total organic carbon content was used to estimate retardation during the transport of chemicals from the site to Lake Michigan (through Section GH) and to Waukegan Harbor (through Section FG). Thus, a change in total organic carbon content should affect mass loading through those sections only, and solely for organic parameters that were assumed to degrade (i.e., benzene and phenol). The total organic carbon content was varied between 0.2 percent and 4 percent during the sensitivity analysis. The results of the sensitivity analysis are shown in Table 8-A-2 for Waukegan Harbor and in Table 8-A-3 for Lake Michigan.

The total organic carbon content variations showed no effect on the mass loading computations to Waukegan Harbor. The TOC value of 0.2 percent had an effect of increasing computed benzene mass loading to Michigan Lake from 0 grams/day to 10 grams/day, and that of phenol from 1 gram/day to 148 gram/day. A TOC value of 4 percent had the effect of reducing the computed mass loadings of both benzene and phenol to 0 grams/day.

Sensitivity to Change in Groundwater Discharge

The sensitivity of the mass loading computations to changes in discharge was assessed by varying the groundwater discharge by plus 50 percent or minus 80 percent. For Sections FG and GH, the range in variation was determined by using the hydraulic conductivity obtained from the pumping test analysis as the maximum value (plus 50 percent) and the geometric mean of hydraulic conductivities obtained from the slug test analyses as the minimum value (minus 80 percent). A range of discharge rates of minus 80 percent to plus 50 percent of the representative discharge rate is also thought to be large enough to adequately account for the uncertainty in discharge rates due to hydraulic gradient and porosity variations. For Sections AB, BC, CD, and DE, the range in discharge rates was determined by increasing the resistance of the harbor walls by 80 percent (which corresponds to an 80 percent decrease in discharge) and decreasing the resistance by 50 percent (which corresponds to an increase in discharge of 50 percent).

For all sections, the mass loading of arsenic, cyanide, and ammonia are directly proportional to the discharge rates. Thus an increase (or a decrease) of 50 percent in the discharge will result in an increase (or a decrease) of 50 percent in the mass loading rate. This proportionality is illustrated in Tables 8-A-2 and 8-A-3.

For benzene and phenol, the relation is the same as above for mass loading computations through Sections AB, BC, CD, and DE, since the flux of mass through these sections is directly proportional to discharge. For Sections FG and GH, the relationship is slightly complicated by the fact that an increase (or decrease) in groundwater discharge may mean an increase (or decrease) in groundwater velocity, which would result in a decrease (or increase) in the amount of benzene and phenol that is degraded. This effect, however, was negligible for Section FG and only slightly noticeable in the computation of benzene and phenol loading to Lake Michigan (Tables 8-A-2 and 8-A-3).

Sensitivity to Vertical Chemical Concentration Distribution

The sensitivity of the mass loading computations to variations in the vertical distribution of chemical concentrations was assessed by varying the vertical distribution by 21 percent of the thickness of the deep portion of the sand aquifer. Given that there is only a 3.5-foot interval of the aquifer that is not screened by monitoring wells, varying the distribution by more than 21 percent did not seem reasonable.

As shown in Tables 8-A-2 and 8-A-3, variations in the vertical distribution resulted in corresponding increases and decreases of 15 to 22 percent in the mass loading estimates.

<u>Summary and Conclusions</u>

A sensitivity analysis of the mass loading rate calculations for benzene, phenol, arsenic, cyanide, and ammonia was performed to account for dilution, variations in total organic carbon content, groundwater discharge rates, and vertical chemical concentration distribution.

The sensitivity analyses were performed by systematically changing one parameter value at a time. The resulting mass loading rates were compared to those computed for the representative case. The range of mass loading rates obtained from the sensitivity analysis for each chemical constituent is summarized in Table 8-A-4.

Accounting for dilution produced only a minor effect on computed mass loading rates for both organic and inorganic parameters. For inorganic parameters, relatively greater sensitivity was observed for mass loading rates computed under variations in vertical chemical concentration distribution and groundwater discharge. For organic parameters, relatively greater sensitivity was observed for mass loading rates to Lake Michigan computed under variations in total organic carbon content. (Variations in total organic carbon content did not affect mass loading rates to Waukegan Harbor).

REFERENCES

Howard, P.H, et al. 1991. Handbook of Environmental Degradation Rates. Lewis Publishers, Chelsea, Michigan.

Luft, P.J. 1984. Modeling of Multicomponent Adsorption onto Granular Carbon in Mixtures of Known and Unknown Composition. Michigan Technological University. Houghton. University Microfilms, Ann Arbor, 1984.

TABLE 8-A-1

COMPUTED CHEMICAL MASS FLUXES
TO WAUKEGAN HARBOR AND LAKE MICHIGAN

COMPOUND	TOTAL COMPUTED MASS DISCHARGE (GRAMS/DAY)	
	WAUKEGAN HARBOR	LAKE MICHIGAN
Benzene	20	0
Phenol	1,700	1
Arsenic	120	170
Cyanide	180	9
Ammonia	40,000	42,000
Total Groundwater Discharge (cu.feet/day)	4,100	3,900

TABLE 8-A-2

SENSITIVITY ANALYSIS
TOTAL COMPUTED MASS DISCHARGES TO WAUKEGAN HARBOR
(GRAMS/DAY)

COMPOUND	REPRESENTATIVE CASE	SENSITIVITY TO DILUTION	SENSITIVITY TO TOC		SENSITIVITY TO DISCHARGE		SENSITIVITY TO CONCENTRATION VERTICAL DISTRIBUTION	
			0.2%	4%	- 80%	+ 50%	- 21%	+ 21%
Benzene	20	20	20	20	4	30	16	23
Phenol	1,700	1,700	1,700	1,700	340	2,600	1,300	2,100
Arsenic	120	120	120	120	24	180	94	140
Cyanide	180	180	180	180	36	270	150	220
Ammonia	40,000	40,000	40,000	40,000	8,000	60,000	32,000	48,000
Overall Effect		No effect.	No effect.	No effect.	Decreased by 80%.	Increased by 50%.	Decreased by 19 to 22%.	Increased by 15 to 22%.

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TABLE 8-A-3

SENSITIVITY ANALYSIS
TOTAL COMPUTED MASS DISCHARGES TO LAKE MICHIGAN
(GRAMS/DAY)

COMPOUND	REPRESENTATIVE CASE	SENSITIVITY TO DILUTION	SENSITIVITY TO TOC		SENSITIVITY TO DISCHARGE		SENSITIVITY TO CONCENTRATION VERTICAL DISTRIBUTION	
			0.2%	4%	- 80%	+ 50%	- 21%	+ 21%
Benzene	0	1	10	0	0	2	0	0
Phenol	1	2	150	0	0	21	1	2
Arsenic	170	170	170	170	33	250	130	200
Cyanide	9	9	9	9	2	14	7	11
Ammonia	42,000	42,000	42,000	42,000	8,400	63,000	33,000	51,000
Overall Effect		No effect.	Phenol and benzene increase by 10 and 150 grams/day, respectively.	Phenol and benzene decrease to 0.	Decreased by 80%.	Increased by 50%.	Decreased by 21%.	Increased by 21%.

TABLE 8-A-4

SENSITIVITY RANGE OF COMPUTED MASS LOADING RATES

COMPOUND	SENSITIVITY RANGE OF TOTAL COMPUTED MASS LOADING RATE (GRAMS/DAY)	
	WAUKEGAN HARBOR	LAKE MICHIGAN
Benzene	4 - 30	0 - 10
Phenol	340 - 2,600	0 - 150
Arsenic	24 - 180	32 - 250
Cyanide	36 - 270	2 - 14
Ammonia	8,000 - 60,000	8,400 - 63,000

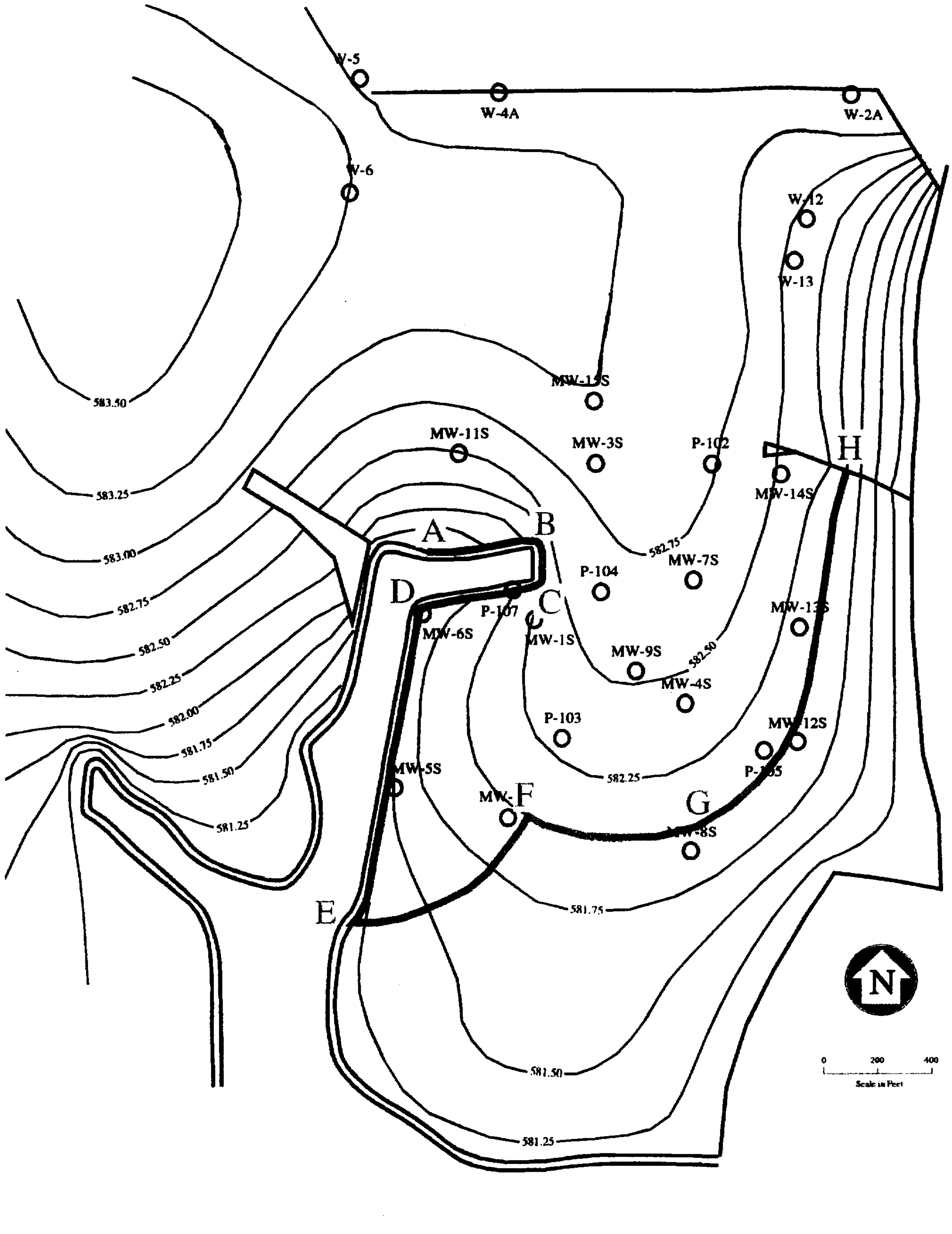

Figure 8-A-1

LOCATION OF SEGMENTS
FOR COMPUTATION OF TOTAL DISCHARGE
USING SITE CALIBRATED SLAEM GROUNDWATER MODEL

Attachment 8-A-1

TABLE 1
COMPUTED CONCENTRATIONS AT SB-51

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

COMPUTED CONCENTRATION AT SB-51

INPUT DATA

OUTPUT DATA

Hydrogeological Unit		Sand Aquifer	
Site Specific Data			
Enter Hydraulic Conductivity		3.00E+01	feet/day
Enter Effective Porosity		0.38	
Enter Hydraulic Gradient		2.60E-03	feet/foot
Enter Distance to Discharge Point		2.50E+02	feet
Enter Soil Bulk Density		1.70E+00	Kg/L
Enter Carbon Content Fraction	Average	2.00E+00	percent

Output		
Groundwater Velocity	75.02	feet/year
Groundwat. Travel Time To Discharge Point	3.3	years

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient		Chemical Travel Time (years)
Benzene	49	--	5.4		17.9
Phenol	27	--	3.4		11.4

	Published Range of Half-lives In Groundwater [1] (years)		Calibrated Half-lives (years)		Fraction Remaining in Groundwater at Discharge Point		Concentration at MW-13D (ug/L)	Measured Concentration at SB-51 (ug/L)	Computed Concentration at SB-51 (ug/L) No dilution	Assumed [2] Concentration at SB-51 Prior to dilution (ug/L)	Computed Concentration at SB-51 Prior to dilution (ug/L)
	Minimum	Maximum	No Dilution	With Dilution	No dilution	With Dilution					
Benzene	0.15	7.9	3.85	4.40	3.95E-02	5.92E-02	1200	47	47	71	71
Phenol	0.02	0.08	1.55	1.68	6.11E-03	9.17E-03	540000	3300	3300	4950	4951

[1] Published in "Howard, P.H., 1991, Handbook of Environmental Degradation Rates, Lewis Publishers, Chelsea, Michigan

[2] A coefficient of dilution of 1.5 is assumed for the sensitivity analysis. This coefficient was inferred from the total cyanide concentrations measured at MW-13D, MW-12D, SB-51, and SB-52.

PROJECT NAME		WAUKEGAN COKE PLANT	
PROJECT NUMBER		13\49-003JSL78	

MASS FLUX TO SECTION:		AB	

INPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Groundwater Flux through Section	3.29E+00	cubic feet/day/foot
Enter Length of Section	420	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.68	
Lower portion of aquifer	0.32	
Total Discharge from Aquifer	1380	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	0	348	0.0	4.4	4.4
Phenol	0	6700	0.0	83.8	83.8
Arsenic	18	2400	0.5	30.0	30.5
Cyanide	0.6	200	0.0	2.5	2.5
Ammonia	1000	550000	26.6	6878.3	6905

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

MASS FLUX TO SECTION:	BC

INPUT DATA

Hydrogeological Unit	Sand Aquifer	
Site Specific Data		
Enter Groundwater Flux through Section	9.28E-01	cubic feet/day/foot
Enter Length of Section	150	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.68	
Lower portion of aquifer	0.32	
Total Discharge from Aquifer	139	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	0	1000	0.0	1.3	1.3
Phenol	0	82700	0.0	104.4	104.4
Arsenic	130	9100	0.3	11.5	11.8
Cyanide	10	200	0.0	0.3	0.3
Ammonia	10500	1150000	28.2	1451.1	1479.3

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

MASS FLUX TO SECTION: CD

INPUT DATA

Hydrogeological Unit Sand Aquifer

Site Specific Data

Enter Groundwater Flux through Section	1.62E+00	cubic feet/day/foot
Enter Length of Section	450	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.68	
Lower portion of aquifer	0.32	
Total Discharge from Aquifer	731	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	31	1000	0.4	6.6	7.1
Phenol	0	162000	0.0	1073.1	1073.1
Arsenic	268	9100	3.8	60.3	64.1
Cyanide	12	354	0.2	2.3	2.5
Ammonia	36000	1700000	506.7	11260.8	11767.5

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION: DE

INPUT DATA			OUTPUT DATA		
Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	60.60	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.10E-03	feet/foot	Groundwat. Travel Time To Discharge Point	0.0	years
Enter Average Saturated Thickness	22.0	feet			
Enter Length of Section	1140	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	1580.04	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	0.00E+00	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	0.0
Phenol	27	--	3.42	0.0
Arsenic	—	6.7	1.00	0.0
Cyanide	—	—	1.00	0.0
Ammonia	—	—	1.00	0.0

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.00E+00
Phenol	0.02	0.08	1.55	1.00E+00
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	22	430	1	6	0.7	6.2	7
Phenol	15	31000	0	444	0.5	443.8	444
Arsenic	0.03	156	0	2	0.0	2.2	2
Cyanide	227	11700	7	168	6.9	167.5	174
Ammonia	16000	1200000	487	17181	486.8	17181.2	17668

PROJECT NAME		WAUKEGAN COKE PLANT
PROJECT NUMBER		13\49-003JSL170

MASS FLUX THROUGH SECTION:	FG

INPUT DATA

OUTPUT DATA

Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	17.31	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	6.00E-04	feet/foot	Groundwat. Travel Time To Discharge Point	67.0	years
Enter Average Saturated Thickness	27.0	feet			
Enter Length of Section	600	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	291.60	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	1.16E+03	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	360.7
Phenol	27	--	3.42	228.9
Arsenic	—	6.7	1.00	67.0
Cyanide	—	—	1.00	67.0
Ammonia	—	—	1.00	67.0

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	6.21E-29
Phenol	0.02	0.08	1.55	3.57E-45
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	16	0.0	0.0	0
Phenol	3	63000	0	166	0.0	0.0	0
Arsenic	10	3400	0	9	0.1	9.0	9
Cyanide	0	550	0	1	0.0	1.5	1
Ammonia	0	800000	0	2114	0.0	2113.9	2114

PROJECT NAME	WAUKEGAN COKE PLANT	
PROJECT NUMBER	13\49-003JSL170	

MASS FLUX THROUGH SECTION: GH

INPUT DATA			OUTPUT DATA		
Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	75.02	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.60E-03	feet/foot	Groundwat. Travel Time To Discharge Point	4.7	years
Enter Average Saturated Thickness	27.5	feet			
Enter Length of Section	1800	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	3861.00	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	3.50E+02	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	5.38	25.1
Phenol	27	–	3.42	15.9
Arsenic	–	6.7	1.00	4.7
Cyanide	–	–	1.00	4.7
Ammonia	–	–	1.00	4.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.09E-02
Phenol	0.02	0.08	1.55	8.04E-04
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	28	0.0	0.3	0
Phenol	0	46100	0	1613	0.0	1.3	1
Arsenic	13	4700	1	164	1.0	164.4	165
Cyanide	0	270	0	9	0.0	9.4	9
Ammonia	0	1200000	0	41984	0.0	41984.0	41984

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	GH - SENSITIVITY TO DILUTION

INPUT DATA

OUTPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	75.02	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.60E-03	feet/foot	Groundwat. Travel Time To Discharge Point	4.7	years
Enter Average Saturated Thickness	27.5	feet			
Enter Length of Section	1800	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	3861.00	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	3.50E+02	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	25.1
Phenol	27	--	3.42	15.9
Arsenic	—	6.7	1.00	4.7
Cyanide	—	—	1.00	4.7
Ammonia	—	—	1.00	4.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	4.40	1.91E-02
Phenol	0.02	0.08	1.68	1.40E-03
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	28	0.0	0.5	1
Phenol	0	46100	0	1613	0.0	2.3	2
Arsenic	13	4700	1	164	1.0	164.4	165
Cyanide	0	270	0	9	0.0	9.4	9
Ammonia	0	1200000	0	41984	0.0	41984.0	41984

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	PG - SENSITIVITY TO TOTAL ORGANIC CARBON

INPUT DATA

OUTPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	17.31	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	6.00E-04	feet/foot	Groundwat. Travel Time To Discharge Point	67.0	years
Enter Average Saturated Thickness	27.0	feet			
Enter Length of Section	600	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	291.60	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	1.16E+03	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E-01	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	1.44	96.4
Phenol	27	--	1.24	83.2
Arsenic	—	6.7	1.00	67.0
Cyanide	—	—	1.00	67.0
Ammonia	—	—	1.00	67.0

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	4.40	2.55E-07
Phenol	0.02	0.08	1.68	1.28E-15
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	16	0.0	0.0	0
Phenol	3	63000	0	166	0.0	0.0	0
Arsenic	10	3400	0	9	0.1	9.0	9
Cyanide	0	550	0	1	0.0	1.5	1
Ammonia	0	800000	0	2114	0.0	2113.9	2114

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	FG - SENSITIVITY TO TOTAL ORGANIC CARBON

INPUT DATA			OUTPUT DATA		
Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	17.31	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	6.00E-04	feet/foot	Groundwat. Travel Time To Discharge Point	67.0	years
Enter Average Saturated Thickness	27.0	feet			
Enter Length of Section	600	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	291.60	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	1.16E+03	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	4.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	9.77	654.5
Phenol	27	–	5.83	390.7
Arsenic	—	6.7	1.00	67.0
Cyanide	—	—	1.00	67.0
Ammonia	—	—	1.00	67.0

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	4.40	1.67E-45
Phenol	0.02	0.08	1.68	1.12E-70
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	16	0.0	0.0	0
Phenol	3	63000	0	166	0.0	0.0	0
Arsenic	10	3400	0	9	0.1	9.0	9
Cyanide	0	550	0	1	0.0	1.5	1
Ammonia	0	800000	0	2114	0.0	2113.9	2114

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	GH - SENSITIVITY TO TOTAL ORGANIC CARBON

INPUT DATA

Hydrogeological Unit	Sand Aquifer	
Site Specific Data		
Enter Hydraulic Conductivity	3.00E+01	feet/day
Enter Effective Porosity	0.38	
Enter Hydraulic Gradient	2.60E-03	feet/foot
Enter Average Saturated Thickness	27.5	feet
Enter Length of Section	1800	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.68	
Lower portion of aquifer	0.32	
Enter Distance to Discharge Point	3.50E+02	feet
Enter Soil Bulk Density	1.70E+00	Kg/L
Enter Carbon Content Fraction	2.00E-01	percent

OUTPUT DATA

Groundwater Velocity	75.02	feet/year
Groundwat. Travel Time To Discharge Point	4.7	years
Total Discharge from Aquifer	3861.00	cubic feet/day

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	1.44	6.7
Phenol	27	–	1.24	5.8
Arsenic	—	6.7	1.00	4.7
Cyanide	—	—	1.00	4.7
Ammonia	—	—	1.00	4.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	4.40	3.47E-01
Phenol	0.02	0.08	1.68	9.18E-02
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	28	0.0	9.8	10
Phenol	0	46100	0	1613	0.0	148.1	148
Arsenic	13	4700	1	164	1.0	164.4	165
Cyanide	0	270	0	9	0.0	9.4	9
Ammonia	0	1200000	0	41984	0.0	41984.0	41984

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION: GH - SENSITIVITY TO TOTAL ORGANIC CARBON

INPUT DATA			OUTPUT DATA		
Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	75.02	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.60E-03	feet/foot	Groundwat. Travel Time To Discharge Point	4.7	years
Enter Average Saturated Thickness	27.5	feet			
Enter Length of Section	1800	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	3861.00	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	3.50E+02	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	4.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	9.77	45.6
Phenol	27	--	5.83	27.2
Arsenic	—	6.7	1.00	4.7
Cyanide	—	—	1.00	4.7
Ammonia	—	—	1.00	4.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	4.40	7.62E-04
Phenol	0.02	0.08	1.68	1.35E-05
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	28	0.0	0.0	0
Phenol	0	46100	0	1613	0.0	0.0	0
Arsenic	13	4700	1	164	1.0	164.4	165
Cyanide	0	270	0	9	0.0	9.4	9
Ammonia	0	1200000	0	41984	0.0	41984.0	41984

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	PG - SENSITIVITY TO GROUNDWATER DISCHARGE

INPUT DATA

OUTPUT DATA

Hydrogeological Unit: Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	6.00E+00	feet/day	Groundwater Velocity	3.46	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	6.00E-04	feet/foot	Groundwat. Travel Time To Discharge Point	335.0	years
Enter Average Saturated Thickness	27.0	feet			
Enter Length of Section	600	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	58.32	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	1.16E+03	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	5.38	1803.7
Phenol	27	–	3.42	1144.3
Arsenic	—	6.7	1.00	335.0
Cyanide	—	—	1.00	335.0
Ammonia	—	—	1.00	335.0

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	9.25E-142
Phenol	0.02	0.08	1.55	5.76E-223
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	3	0.0	0.0	0
Phenol	3	63000	0	33	0.0	0.0	0
Arsenic	10	3400	0	2	0.0	1.8	2
Cyanide	0	550	0	0	0.0	0.3	0
Ammonia	0	800000	0	423	0.0	422.8	423

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	GH - SENSITIVITY TO GROUNDWATER DISCHARGE

INPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	6.00E+00	feet/day
Enter Effective Porosity	0.38	
Enter Hydraulic Gradient	2.60E-03	feet/foot
Enter Average Saturated Thickness	27.5	feet
Enter Length of Section	1800	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.68	
Lower portion of aquifer	0.32	
Enter Distance to Discharge Point	3.50E+02	feet
Enter Soil Bulk Density	1.70E+00	Kg/L
Enter Carbon Content Fraction	2.00E+00	percent

OUTPUT DATA

Groundwater Velocity	15.00	feet/year
Groundwat. Travel Time To Discharge Point	23.3	years
Total Discharge from Aquifer	772.20	cubic feet/day

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	125.6
Phenol	27	--	3.42	79.7
Arsenic	—	6.7	1.00	23.3
Cyanide	—	—	1.00	23.3
Ammonia	—	—	1.00	23.3

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.51E-10
Phenol	0.02	0.08	1.55	3.36E-16
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	6	0.0	0.0	0
Phenol	0	46100	0	323	0.0	0.0	0
Arsenic	13	4700	0	33	0.2	32.9	33
Cyanide	0	270	0	2	0.0	1.9	2
Ammonia	0	1200000	0	8397	0.0	8396.8	8397

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	PG - SENSITIVITY TO GROUNDWATER DISCHARGE

INPUT DATA			OUTPUT DATA		
Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	4.50E+01	feet/day	Groundwater Velocity	25.97	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	6.00E-04	feet/foot	Groundwat. Travel Time To Discharge Point	44.7	years
Enter Average Saturated Thickness	27.0	feet			
Enter Length of Section	600	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.68		Total Discharge from Aquifer	437.40	cubic feet/day
Lower portion of aquifer	0.32				
Enter Distance to Discharge Point	1.16E+03	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	5.38	240.5
Phenol	27	–	3.42	152.6
Arsenic	—	6.7	1.00	44.7
Cyanide	—	—	1.00	44.7
Ammonia	—	—	1.00	44.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.57E-19
Phenol	0.02	0.08	1.55	2.33E-30
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	24	0.0	0.0	0
Phenol	3	63000	0	250	0.0	0.0	0
Arsenic	10	3400	0	13	0.1	13.5	14
Cyanide	0	550	0	2	0.0	2.2	2
Ammonia	0	800000	0	3171	0.0	3170.8	3171

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX THROUGH SECTION:	GH - SENSITIVITY TO GROUNDWATER DISCHARGE

INPUT DATA

Hydrogeological Unit	Sand Aquifer	
Site Specific Data		
Enter Hydraulic Conductivity	4.50E+01	feet/day
Enter Effective Porosity	0.38	
Enter Hydraulic Gradient	2.60E-03	feet/foot
Enter Average Saturated Thickness	27.5	feet
Enter Length of Section	1800	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.68	
Lower portion of aquifer	0.32	
Enter Distance to Discharge Point	3.50E+02	feet
Enter Soil Bulk Density	1.70E+00	Kg/L
Enter Carbon Content Fraction	2.00E+00	percent

OUTPUT DATA

Groundwater Velocity	112.54	feet/year
Groundwat. Travel Time To Discharge Point	3.1	years
Total Discharge from Aquifer	5791.50	cubic feet/day

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	16.7
Phenol	27	--	3.42	10.6
Arsenic	—	6.7	1.00	3.1
Cyanide	—	—	1.00	3.1
Ammonia	—	—	1.00	3.1

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	4.91E-02
Phenol	0.02	0.08	1.55	8.65E-03
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	42	0.0	2.1	2
Phenol	0	46100	0	2419	0.0	20.9	21
Arsenic	13	4700	1	247	1.4	246.7	248
Cyanide	0	270	0	14	0.0	14.2	14
Ammonia	0	1200000	0	62976	0.0	62976.0	62976

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	AB - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Groundwater Flux through Section	3.29E+00	cubic feet/day/foot
Enter Length of Section	420	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.75	
Lower portion of aquifer	0.25	
Total Discharge from Aquifer	1380	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	0	348	0.0	3.4	3.4
Phenol	0	6700	0.0	66.0	66.0
Arsenic	18	2400	0.5	23.6	24.2
Cyanide	0.6	200	0.0	2.0	2.0
Ammonia	1000	550000	29.2	5416.7	5446

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	AB - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Groundwater Flux through Section	3.29E+00	cubic feet/day/foot
Enter Length of Section	420	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.61	
Lower portion of aquifer	0.39	
Total Discharge from Aquifer	1380	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	0	348	0.0	5.3	5.3
Phenol	0	6700	0.0	101.6	101.6
Arsenic	18	2400	0.4	36.4	36.8
Cyanide	0.6	200	0.0	3.0	3.0
Ammonia	1000	550000	23.9	8340.0	8364

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

MASS FLUX TO SECTION:	BC - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit Sand Aquifer

Site Specific Data

Enter Groundwater Flux through Section	9.28E-01	cubic feet/day/foot
Enter Length of Section	150	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.75	
Lower portion of aquifer	0.25	
Total Discharge from Aquifer	139	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	0	1000	0.0	1.0	1.0
Phenol	0	82700	0.0	82.2	82.2
Arsenic	130	9100	0.4	9.0	9.4
Cyanide	10	200	0.0	0.2	0.2
Ammonia	10500	1150000	31.0	1142.7	1173.7

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

MASS FLUX TO SECTION:	BC - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit — **Sand Aquifer**

Site Specific Data

Enter Groundwater Flux through Section	9.28E-01	cubic feet/day/foot
Enter Length of Section	150	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.61	
Lower portion of aquifer	0.39	
Total Discharge from Aquifer	139	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	0	1000	0.0	1.5	1.5
Phenol	0	82700	0.0	126.5	126.5
Arsenic	130	9100	0.3	13.9	14.2
Cyanide	10	200	0.0	0.3	0.3
Ammonia	10500	1150000	25.3	1759.5	1784.8

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

MASS FLUX TO SECTION:	CD - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit Sand Aquifer

Site Specific Data

Enter Groundwater Flux through Section	1.62E+00	cubic feet/day/foot
Enter Length of Section	450	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.75	
Lower portion of aquifer	0.25	
Total Discharge from Aquifer	731	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	31	1000	0.5	5.2	5.7
Phenol	0	162000	0.0	845.1	845.1
Arsenic	268	9100	4.1	47.5	51.6
Cyanide	12	354	0.2	1.8	2.0
Ammonia	36000	1700000	557.4	8867.9	9425.3

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL78

MASS FLUX TO SECTION:	CD - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit — **Sand Aquifer**

Site Specific Data

Enter Groundwater Flux through Section	1.62E+00	cubic feet/day/foot
Enter Length of Section	450	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.61	
Lower portion of aquifer	0.39	
Total Discharge from Aquifer	731	cubic feet/day

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Upper and Lower portions of Aqu.) (g/day)
Benzene	31	1000	0.4	8.0	8.4
Phenol	0	162000	0.0	1301.1	1301.1
Arsenic	268	9100	3.4	73.1	76.5
Cyanide	12	354	0.2	2.8	3.0
Ammonia	36000	1700000	456.1	13653.7	14109.8

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	DE - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

OUTPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	60.60	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.10E-03	feet/foot	Groundwat. Travel Time To Discharge Point	0.0	years
Enter Average Saturated Thickness	22.0	feet			
Enter Length of Section	1140	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.75		Total Discharge from Aquifer	1580.04	cubic feet/day
Lower portion of aquifer	0.25				
Enter Distance to Discharge Point	0.00E+00	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)	
Benzene	49	–	5.38	0.0	
Phenol	27	–	3.42	0.0	
Arsenic	–	6.7	1.00	0.0	
Cyanide	–	–	1.00	0.0	
Ammonia	–	–	1.00	0.0	

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.00E+00
Phenol	0.02	0.08	1.55	1.00E+00
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	22	430	1	5	0.7	4.8	6
Phenol	15	31000	1	350	0.5	349.5	350
Arsenic	0.03	156	0	2	0.0	1.8	2
Cyanide	227	11700	8	132	7.6	131.9	140
Ammonia	16000	1200000	535	13530	535.5	13530.2	14066

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	DE - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	3.00E+01	feet/day
Enter Effective Porosity	0.38	
Enter Hydraulic Gradient	2.10E-03	feet/foot
Enter Average Saturated Thickness	22.0	feet
Enter Length of Section	1140	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.61	
Lower portion of aquifer	0.39	
Enter Distance to Discharge Point	0.00E+00	feet
Enter Soil Bulk Density	1.70E+00	Kg/L
Enter Carbon Content Fraction	2.00E+00	percent

OUTPUT DATA

Groundwater Velocity	60.60	feet/year
Groundwat. Travel Time To Discharge Point	0.0	years
Total Discharge from Aquifer	1580.04	cubic feet/day

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	0.0
Phenol	27	--	3.42	0.0
Arsenic	—	6.7	1.00	0.0
Cyanide	—	—	1.00	0.0
Ammonia	—	—	1.00	0.0

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.00E+00
Phenol	0.02	0.08	1.55	1.00E+00
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	22	430	1	7	0.6	7.5	8
Phenol	15	31000	0	538	0.4	538.2	539
Arsenic	0.03	156	0	3	0.0	2.7	3
Cyanide	227	11700	6	203	6.2	203.1	209
Ammonia	16000	1200000	438	20832	438.1	20832.2	21270

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	PG - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit	Sand Aquifer	
Site Specific Data		
Enter Hydraulic Conductivity	3.00E+01	feet/day
Enter Effective Porosity	0.38	
Enter Hydraulic Gradient	6.00E-04	feet/foot
Enter Average Saturated Thickness	27.0	feet
Enter Length of Section	600	feet
Enter Vertical Chemical Distibution		
Upper portion of aquifer	0.75	
Lower portion of aquifer	0.25	
Enter Distance to Discharge Point	1.16E+03	feet
Enter Soil Bulk Density	1.70E+00	Kg/L
Enter Carbon Content Fraction	2.00E+00	percent

OUTPUT DATA

Groundwater Velocity	17.31	feet/year
Groundwat. Travel Time To Discharge Point	67.0	years
Total Discharge from Aquifer	291.60	cubic feet/day

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	5.38	360.7
Phenol	27	–	3.42	228.9
Arsenic	—	6.7	1.00	67.0
Cyanide	—	—	1.00	67.0
Ammonia	—	—	1.00	67.0

	Published Range of Half-lives In Groundwater (years)		Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
	Minimum	Maximum		
Benzene	0.15	7.9	3.85	6.21E-29
Phenol	0.02	0.08	1.55	3.57E-45
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	13	0.0	0.0	0
Phenol	3	63000	0	131	0.0	0.0	0
Arsenic	10	3400	0	7	0.1	7.1	7
Cyanide	0	550	0	1	0.0	1.1	1
Ammonia	0	800000	0	1665	0.0	1664.7	1665

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	FG - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

OUTPUT DATA

Hydrogeological Unit	Sand Aquifer				
Site Specific Data					
Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	17.31	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	6.00E-04	feet/foot	Groundwat. Travel Time To Discharge Point	67.0	years
Enter Average Saturated Thickness	27.0	feet			
Enter Length of Section	600	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.61		Total Discharge from Aquifer	291.60	cubic feet/day
Lower portion of aquifer	0.39				
Enter Distance to Discharge Point	1.16E+03	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)	
Benzene	49	--	5.38	360.7	
Phenol	27	--	3.42	228.9	
Arsenic	—	6.7	1.00	67.0	
Cyanide	—	—	1.00	67.0	
Ammonia	—	—	1.00	67.0	

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	6.21E-29
Phenol	0.02	0.08	1.55	3.57E-45
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	1	6100	0	20	0.0	0.0	0
Phenol	3	63000	0	202	0.0	0.0	0
Arsenic	10	3400	0	11	0.1	10.9	11
Cyanide	0	550	0	2	0.0	1.8	2
Ammonia	0	800000	0	2563	0.0	2563.1	2563

PROJECT NAME	WAUKEGAN COKE PLANT
PROJECT NUMBER	13\49-003JSL170

MASS FLUX TO SECTION:	GH - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

OUTPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	75.02	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.60E-03	feet/foot	Groundwat. Travel Time To Discharge Point	4.7	years
Enter Average Saturated Thickness	27.5	feet			
Enter Length of Section	1800	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.75		Total Discharge from Aquifer	3861.00	cubic feet/day
Lower portion of aquifer	0.25				
Enter Distance to Discharge Point	3.50E+02	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	--	5.38	25.1
Phenol	27	--	3.42	15.9
Arsenic	—	6.7	1.00	4.7
Cyanide	—	—	1.00	4.7
Ammonia	—	—	1.00	4.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.09E-02
Phenol	0.02	0.08	1.55	8.04E-04
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	22	0.0	0.2	0
Phenol	0	46100	0	1270	0.0	1.0	1
Arsenic	13	4700	1	129	1.1	129.5	131
Cyanide	0	270	0	7	0.0	7.4	7
Ammonia	0	1200000	0	33062	0.0	33062.4	33062

PROJECT NAME		WAUKEGAN COKE PLANT
PROJECT NUMBER		13\49-003JSL170

MASS FLUX TO SECTION:		GH - SENSITIVITY TO VERTICAL DISTRIBUTION OF CONTAMINANTS

INPUT DATA

Hydrogeological Unit — Sand Aquifer

Site Specific Data

Enter Hydraulic Conductivity	3.00E+01	feet/day	Groundwater Velocity	75.02	feet/year
Enter Effective Porosity	0.38				
Enter Hydraulic Gradient	2.60E-03	feet/foot	Groundwat. Travel Time To Discharge Point	4.7	years
Enter Average Saturated Thickness	27.5	feet			
Enter Length of Section	1800	feet			
Enter Vertical Chemical Distibution					
Upper portion of aquifer	0.61		Total Discharge from Aquifer	3861.00	cubic feet/day
Lower portion of aquifer	0.39				
Enter Distance to Discharge Point	3.50E+02	feet			
Enter Soil Bulk Density	1.70E+00	Kg/L			
Enter Carbon Content Fraction	2.00E+00	percent			

OUTPUT DATA

	Soil Sorption Coefficient Koc (L/Kg)	Distribution Factor Kd (L/Kg)	Retardation Coefficient	Chemical Travel Time (years)
Benzene	49	–	5.38	25.1
Phenol	27	–	3.42	15.9
Arsenic	_	6.7	1.00	4.7
Cyanide	_	_	1.00	4.7
Ammonia	_	_	1.00	4.7

	Published Range of Half-lives In Groundwater (years) Minimum	Maximum	Calibrated Half-lives (years)	Fraction Remaining in Groundwater at Discharge Point
Benzene	0.15	7.9	3.85	1.09E-02
Phenol	0.02	0.08	1.55	8.04E-04
Arsenic	NA	NA	NA	1.00E+00
Cyanide	NA	NA	NA	1.00E+00
Ammonia	NA	NA	NA	1.00E+00

	Computed Average Concentration in Section (Up. port. of Aqu.) (ug/L)	Computed Average Concentration in Section (Low. port. of Aqu.) (ug/L)	Computed Mass Flux at Section (Upper Portion of Aquifer) (g/day)	Computed Mass Flux at Section (Lower Portion of Aquifer) (g/day)	Computed Mass Flux At Discharge Point (g/day) (Upper Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Lower Portion of Aquifer)	Computed Mass Flux At Discharge Point (g/day) (Entire Section) of Aquifer)
Benzene	0	804	0	34	0.0	0.4	0
Phenol	0	46100	0	1956	0.0	1.6	2
Arsenic	13	4700	1	199	0.9	199.4	200
Cyanide	0	270	0	11	0.0	11.5	11
Ammonia	0	1200000	0	50906	0.0	50905.6	50906

Appendix 8-B

Contaminant Transport Analysis

APPENDIX 8-B
CONTAMINANT TRANSPORT ANALYSES

INTRODUCTION AND OBJECTIVES

As a result of the WCP site's position on the peninsula between Waukegan Harbor and Lake Michigan, the areal extent of existing and potential contaminant transport in groundwater is limited. The downgradient extent of contaminant transport to the west is defined by groundwater quality data from monitoring well nests placed in the immediate vicinity of the harbor wall. Contaminant transport to the east is defined by groundwater quality data from monitoring well nests placed on the beach east of the site, and by data for in situ groundwater samples collected from borings placed further to the east. Contaminant transport to the north is limited, as defined by groundwater quality data from monitoring wells placed near the northern boundary of the site and by groundwater flow patterns that show little potential for transport to the north. Accordingly, the available groundwater quality data describe contaminant transport to the west, east, and north of the site.

Groundwater flow patterns and groundwater quality data from monitoring wells screened in the deep portion of the sand aquifer at the southern boundary of the site indicate the potential for off-site transport to the south. The potential areal extent of contaminant transport to the south is necessarily limited by the limited areal extent of the peninsula. The contaminant transport simulations described in this appendix were performed to provide supplemental information about potential contaminant distributions in groundwater within this area south of the WCP site. The results of the simulations will be relevant to: (1) future evaluations of potential groundwater remedies (i.e., assessments of groundwater extraction and/or containment systems); and (2) associated predesign studies (i.e., groundwater quality investigations to refine final design parameters for extraction and/or containment systems).

COMPUTER CODE

The MYGRT Version 2.0 computer code (EPRI, 1989) was used for the contaminant transport simulations. As described in the April 1993 Revised Technical Memorandum describing proposed modeling for the WCP RI/FS (Barr, 1993), the MYGRT code is a two-dimensional model for simulating the transient migration of organic and inorganic chemicals in groundwater. The code accounts for advection, dispersion, retardation (attenuation), and degradation. A summary of the theoretical basis of the code was provided with the April 1993 Revised Technical Memorandum (Barr, 1993).

APPROACH TO SIMULATIONS

The MYGRT code was used to develop two-dimensional simulations of horizontal contaminant transport along selected flow paths originating at the southern boundary of the WCP site. Groundwater flow paths for areas south of the WCP site were evaluated based on groundwater elevation data (Section 5.2.1) and on the results of groundwater flow simulations (Section 5.2.2). The contaminant transport modeling incorporates these measured and simulated flow conditions as representative of conditions during MGP/coking operations (i.e., 1927 to 1972). A groundwater flow path was identified for evaluating potential contaminant transport south of the site; two additional flow paths were selected for evaluating potential transport southwest and southeast of the site. The selected flow paths are shown on Figure 8-B-1.

Because groundwater quality data indicate that higher concentrations of relatively mobile constituents (e.g., BETX and phenolic compounds, arsenic, and cyanide) occur essentially in the deep portion of the sand aquifer, simulations were performed to assess contaminant transport in this zone. The simulations reflect transport within the lower 8 to 10 feet of the aquifer; accordingly, potential concentration reductions due to dilution from infiltration reaching the water table are not considered.

Simulation input parameters, parameter values, and the rationale for parameter value selection are summarized in Table 8-B-1. Simulation input files are in Attachment 8-B-1.

Transport simulations were performed for assumed constant concentration sources at the southern site boundary. Results for downgradient locations to the south were computed as relative percentages of the assigned source concentration. If historical constituent concentrations at the southern site boundary were similar to those measured during the RI, the transport simulation results for areas to the south may be interpreted relative to observed groundwater quality data for the relevant constituents (Section 7.7.2). However, as discussed in the April 1993 Revised Technical Memorandum (Barr, 1993), the WCP site involves multiple source areas that may have contributed different chemical constituents to the groundwater over different time frames. As a result, it is possible that historical constituent concentrations in groundwater at the southern site boundary were higher or lower than those measured during the RI. As such, the relative concentration approach used for the transport simulations provides the most appropriate basis for evaluating both current observed groundwater quality conditions and possible historical groundwater quality conditions.

SIMULATION RESULTS

Transport simulation results are shown on Figures 8-B-2 through 8-B-21. The figures show relative concentrations (as a percentage of the assumed constant concentration assigned at the southern site boundary) versus time along each of the three selected flow paths. Results are shown for organic parameters (benzene and phenol) and inorganic parameters (arsenic and cyanide), based on the site-representative input parameter values listed in Table 8-B-1. Results are also shown for sensitivity analyses.

SENSITIVITY ANALYSIS

Sensitivity analyses were performed to evaluate: (1) the effects of potential variation in retardation factors (Table 8-B-1); (2) the influence of the assigned site-representative degradation rate constants (by also calculating results for zero degradation; assigning higher degradation rate constants based on literature values would result in less extensive migration than is computed using the site-representative values); (3) the effects of potential variation in longitudinal and transverse dispersivity; and (4) the effects of potential variation in groundwater flow velocity. Table 8-B-1 describes the values and rationale for the range of variation for each sensitivity parameter. The following sections describe the results of the sensitivity analyses for: (1) inorganic constituents; and (2) organic constituents.

Inorganic Constituents

For inorganic parameters that show little or no retardation/degradation, sensitivity analyses involved varying longitudinal dispersivity, transverse dispersivity, and groundwater flow velocity.

Longitudinal Dispersivity

Because of hydrodynamic dispersion, the concentration of a solute will decrease with distance from the source. In addition, the greater the longitudinal dispersivity, the more gradual the decrease becomes. This point is illustrated on Figure 8-B-20. At a point along the flow path that is ahead of the solute front (> 300 m on Figure 8-B-20), an increase in dispersivity will increase the concentration at a given travel time. At a point behind the solute front, an increase in dispersivity will decrease the concentration at a given travel time.

Transverse Dispersivity

As shown on Figure 8-B-21, an increase in transverse dispersivity will result in a decrease in concentrations along the flow path for a given travel time.

A comparison of Figures 8-B-20 and 8-B-21 indicates that variations in longitudinal dispersivity result in greater changes in concentration along the flow path at a given travel time, compared to the effects of variations in transverse dispersivity.

Groundwater Flow Velocity

The greater the groundwater flow velocity, the faster a solute front will arrive at a point along the flow path. As shown on Figure 8-B-22, the solute front for the minimum velocity has not reached the end of the flow path for the simulated transport time, while the solute front for the maximum velocity has passed the end of the flow path.

Comparative Sensitivities

The contaminant transport simulations for inorganic parameters are most sensitive to variations in groundwater flow velocity and least sensitive to variations in transverse dispersivity.

<u>Organic Constituents</u>

For organic constituents, sensitivity analyses involved varying retardation and degradation rates in addition to varying longitudinal dispersivity, transverse dispersivity, and groundwater flow velocity.

Retardation/Degradation

As shown on Figures 8-B-10 and 8-B-11, minimizing retardation rates and decreasing degradation rates to zero both result in increases in concentrations at a point along the flow path at a given time. When compared to the representative simulation on Figure 8-B-10, the effects of decreasing degradation rates to zero are greater than those of minimizing retardation.

Longitudinal Dispersivity

As illustrated on Figure 8-B-20, increasing longitudinal dispersivity results in an increase in constituent concentrations along the entire length of the flow path for a given travel time. Constituents are also transported a relatively greater distance from the source along the flow path.

Transverse Dispersivity

Increasing transverse dispersivity does not result in significant variations in predicted concentrations along the flow path for a given travel time. This point is illustrated on Figures 8-B-10 and 8-B-21.

Groundwater Flow Velocity

As illustrated on Figure 8-B-22, increasing groundwater flow velocity results in an increase in constituent concentrations along the entire length of the flow path for a given time. Constituents are also transported a relatively greater distance from the source along the flow path.

Comparative Sensitivities

The contaminant transport simulations for organic parameters are most sensitive to variations in degradation rates. The simulations are less sensitive to minimizing retardation and maximizing longitudinal dispersivity. The simulations are even less sensitive to changes in groundwater flow velocity and least sensitive to transverse dispersivity.

CONCLUSIONS

The contaminant transport and sensitivity simulations indicate that for areas of the deep portion of the sand aquifer located south of the WCP site:

- Inorganic constituents that show little or no retardation/degradation are likely to be present in groundwater south of the site at concentrations similar to historical concentrations at the southern site boundary. Concentrations in more distant areas directly south of the site are likely to show reductions from historical source concentrations due to dispersion.

- Organic constituents susceptible to attenuation and degradation processes are likely to show significant decreases from concentrations that have historically been present at the southern site boundary. Along shorter flow paths toward Waukegan Harbor (i.e., to the southwest) and Lake Michigan (i.e., to the southeast), the simulation results indicate that concentrations of such constituents may reach the ends of the flow paths, but at dramatically reduced concentrations. Along longer flow paths toward the harbor entrance channel (i.e., to the south), the simulation results suggest that such constituents would not have reached the ends of the flow paths for the examined travel times.

The conclusions derived from the contaminant transport simulations are generally consistent with trends in measured groundwater quality data for the deep portion of the sand aquifer (Section 7.7.2). As is the case for the transport simulation results, the measured concentrations in areas reflecting off-site transport (to the east) generally show more significant decreases with distance from the site for organic constituents than for inorganic constituents. However, arsenic (modeled assuming no retardation) may be attenuated due to adsorption onto aquifer solids (Sections 6.2.2 and 8.1.2); accordingly, the contaminant transport simulations for arsenic represent worst-case scenarios in terms of extent of migration. The sensitivity analyses performed provide information about the effects of parameter variation on model results, as described above, but do not alter conclusions derived from the representative case contaminant transport simulations.

The contaminant transport simulation results suggest that: (1) if implemented, groundwater remedies will likely need to address areas south of the WCP site; and (2) limited predesign groundwater quality investigations could be implemented to provide information for final remedy design.

REFERENCES

Barr Engineering Company. 1993. Revised Technical Memorandum, Proposed Modeling for RI/FS; Waukegan Manufactured Gas and Coke Plant Site. April 12, 1993.

Electric Power Research Institute. 1989. MYGRT Code Version 2.0: An IBM Code for Simulating Migration of Organic and Inorganic Chemicals in Groundwater. Prepared by Tetra Tech, Inc., Lafayette, California. Publication EN-6531, Research Project 2879-2.

Shimp, N.F., J. Schleicher, R. Ruch, D. Heck, and H. Leland. 1971. Trace element and Organic Carbon Accumulation in the Most Recent Sediments of Southern Lake Michigan, Illinois State Geological Survey, Environmental Geology Notes, Number 41.

Walton, William C. 1984. Practical Aspects of Ground Water Modeling. National Water Well Association.

TABLE 8-B-1

INPUT PARAMETER SUMMARY, CONTAMINANT TRANSPORT SIMULATIONS

PARAMETER	VALUE	RATIONALE/RELEVANCE
Hydraulic Conductivity (K)	30 ft/day	Rep. value (Section 5.2.1) with sensitivity range of 5 ft/day (geometric mean of slug test results) to 47 ft/day (pumping test results)/used in pore velocity calculations.
Hydraulic Gradient (I)	0.0011 (SW) 0.00075 (S) 0.0017 (SE)	Avg. values from flow modeling results (Section 5.2.2)/used in pore velocity calculations.
Porosity (n)	38%	Avg. value (Section 5.2.1)/used in pore velocity calculations.
Flow Path Length	600 ft. (SW) 1,100 ft. (S) 500 ft. (SE)	Values from flow model results/defines simulation domains.
Source Width	400 ft. (SW) 400 ft. (S) 350 ft. (SE)	Flow path specific (Figure 8-B-1)/characterizes extent of contamination perpendicular to each flow path.
Source Concentration (C_o)	100	Assumed source concentration/simulation results interpreted as % of source concentration.
Transport Times	20 yr. 45 yr. 65 yr.	Approximate times since 1927, 1949, and 1972/times since beginning, mid-point, and end of MGP/coking operations.
Chemical Constituents	Benzene Phenol Arsenic Cyanide	Relatively mobile constituents representative of organic and inorganic parameter groups, identified at concentrations of concern in deep portion of sand aquifer/constituents selected to illustrate simulation results.
Longitudinal Dispersivity (α_L)	60 ft. (SW) 110 ft. (S) 50 ft. (SE)	0.1 times flow path length with sensitivity range of 0.01 to 1 times flow path length for flow path lengths of 10 to 100 m (Walton, 1984)/describes degree of spreading in direction of flow.
Transverse Dispersivity (α_T)	6 ft. (SW) 11 ft. (S) 5 ft. (SE)	0.1 times α_L with sensitivity range of 0.04 to 0.30 times α_L (Walton, 1984)/describes degree of spreading perpendicular to flow.
Retardation Factor (R_d)	5.4, 1.4 (benzene) 3.4, 1.2 (phenol) 1.0, 1.0 (arsenic & cyanide)	Calculated for TOC = 2% (Section 8.1.2) and 0.2% (Shimp, et al., 1971) from data in Table 6.2-1/describes degree of attenuation for organic compounds (no retardation assumed for inorganic compounds).
Degradation Constant (K_b)	0.18 yr^{-1} (benzene) 0.45 yr^{-1} (phenol) 0.00 (arsenic & cyanide)	Site-rep. values (Appendix 8-A), with sensitivity analyses performed assuming no degradation/describes estimated rate of biodegradation and other decay mechanisms.

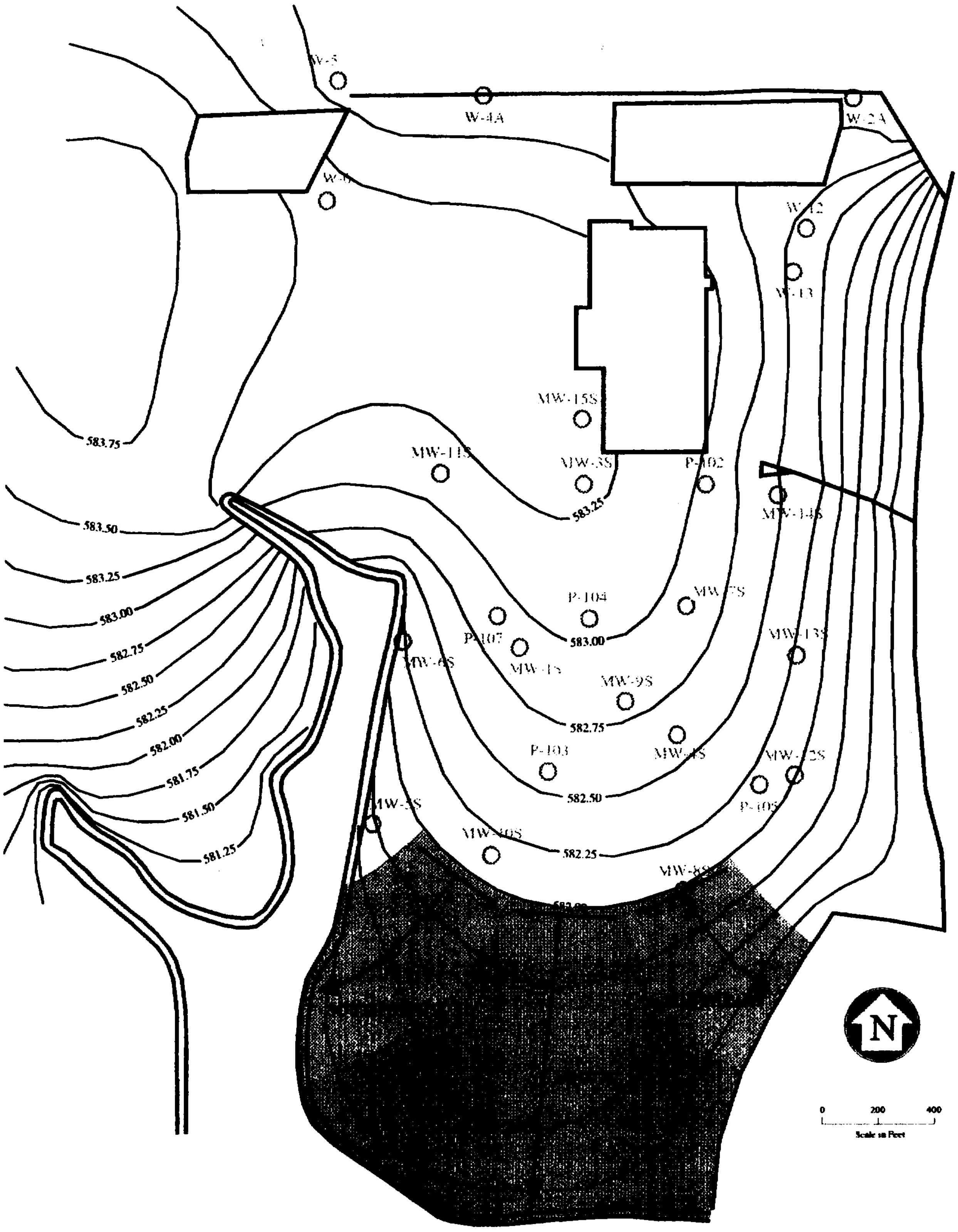

Figure 8-B-1

FLOW PATHS SELECTED FOR TRANSPORT SIMULATIONS

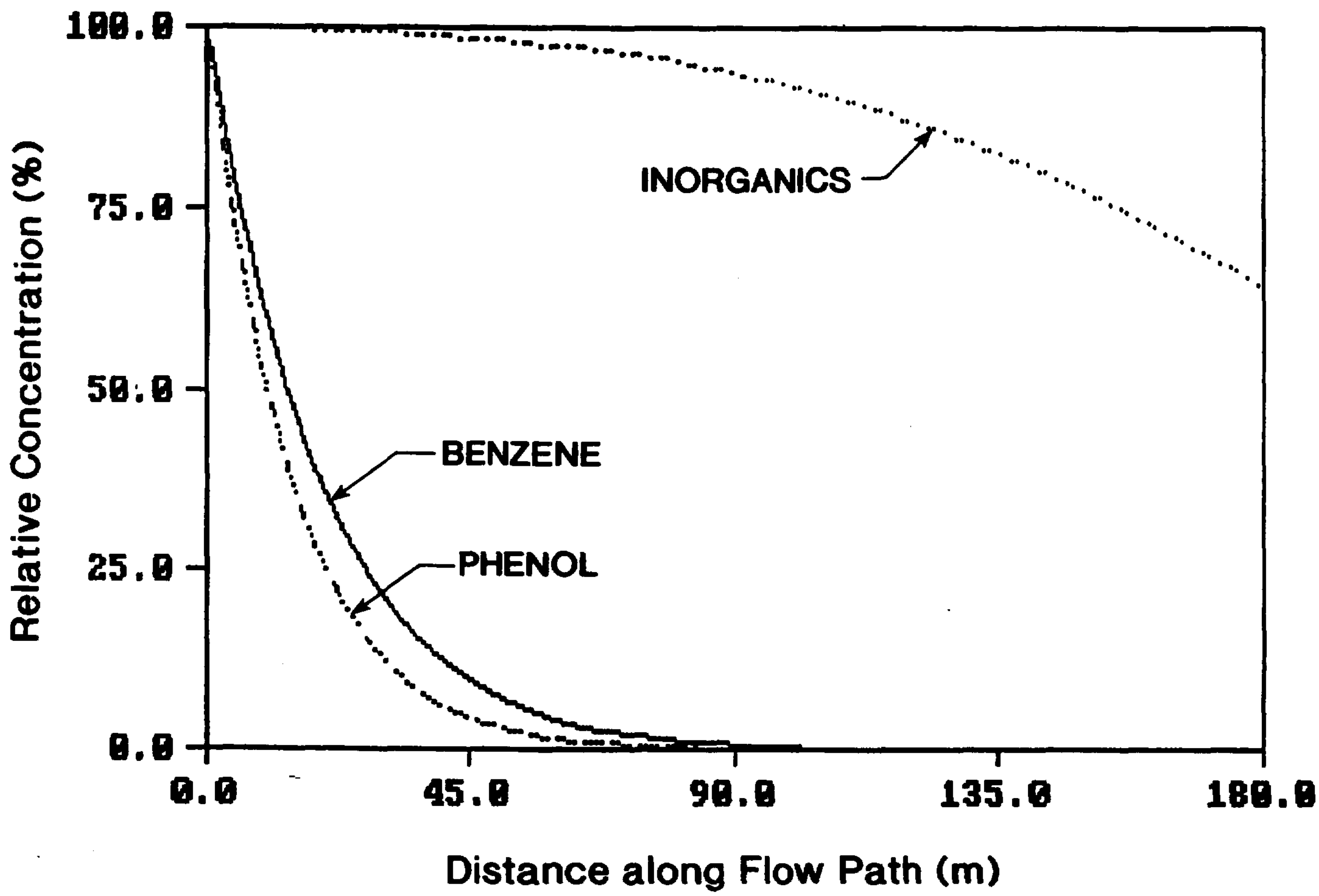

Figure 8-B-2

RESULTS FOR SW FLOW PATH, t = 20 YR.
(Site-Representative Parameters)

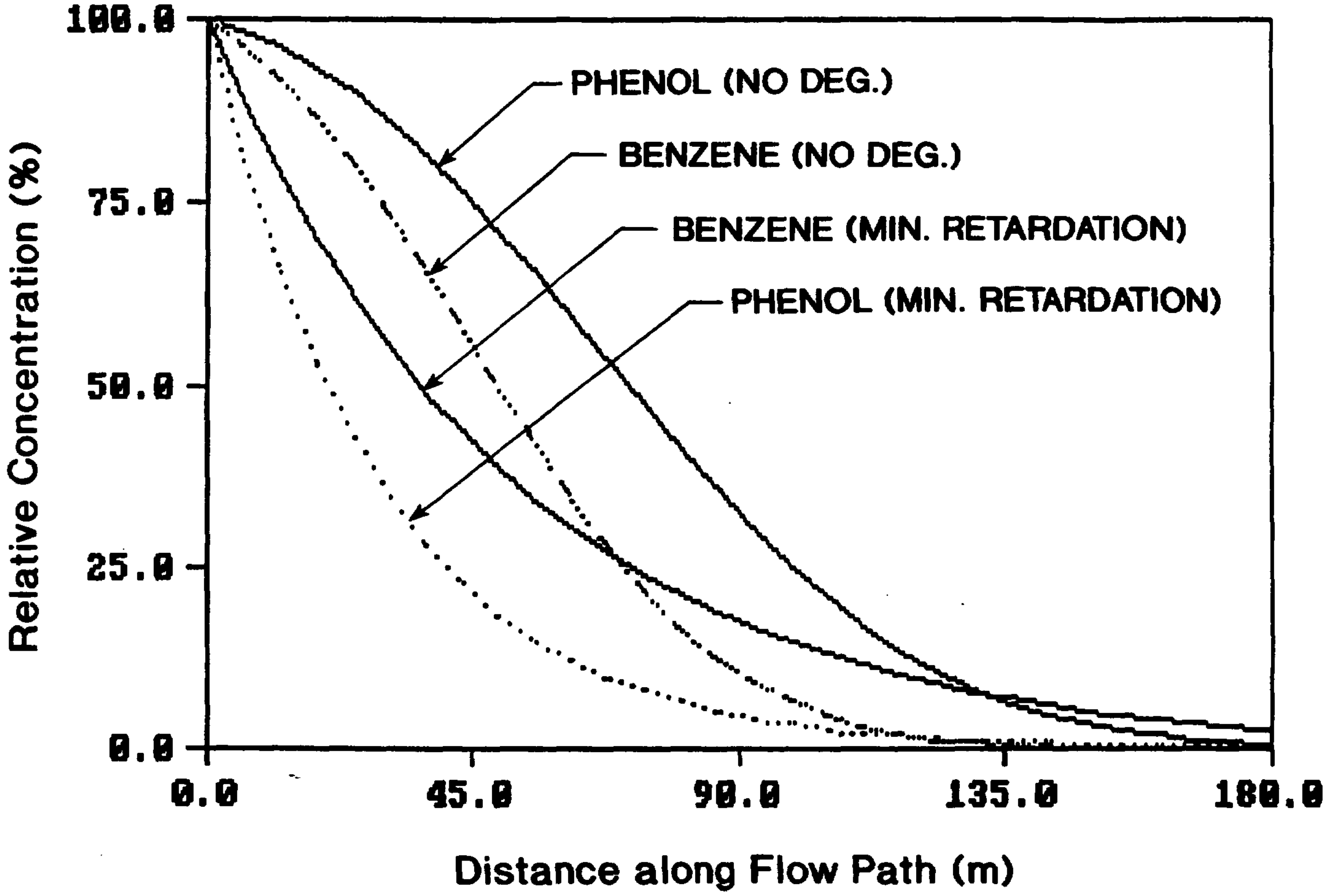

Figure 8-B-3

RESULTS FOR SW FLOW PATH, t = 20 YR.
(Sensitivity Parameters)

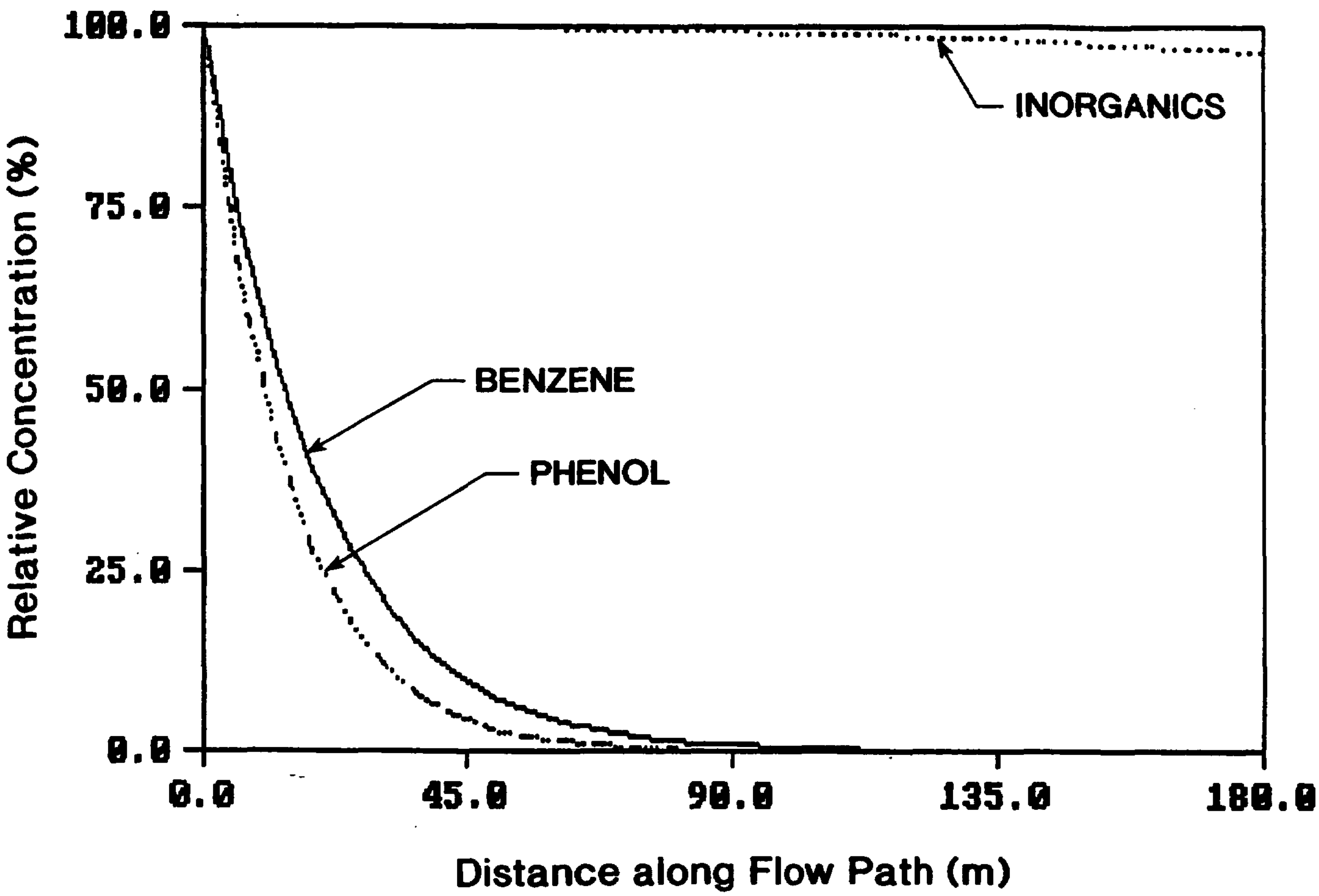

Figure 8-B-4

RESULTS FOR SW FLOW PATH, t = 45 YR.
(Site-Representative Parameters)

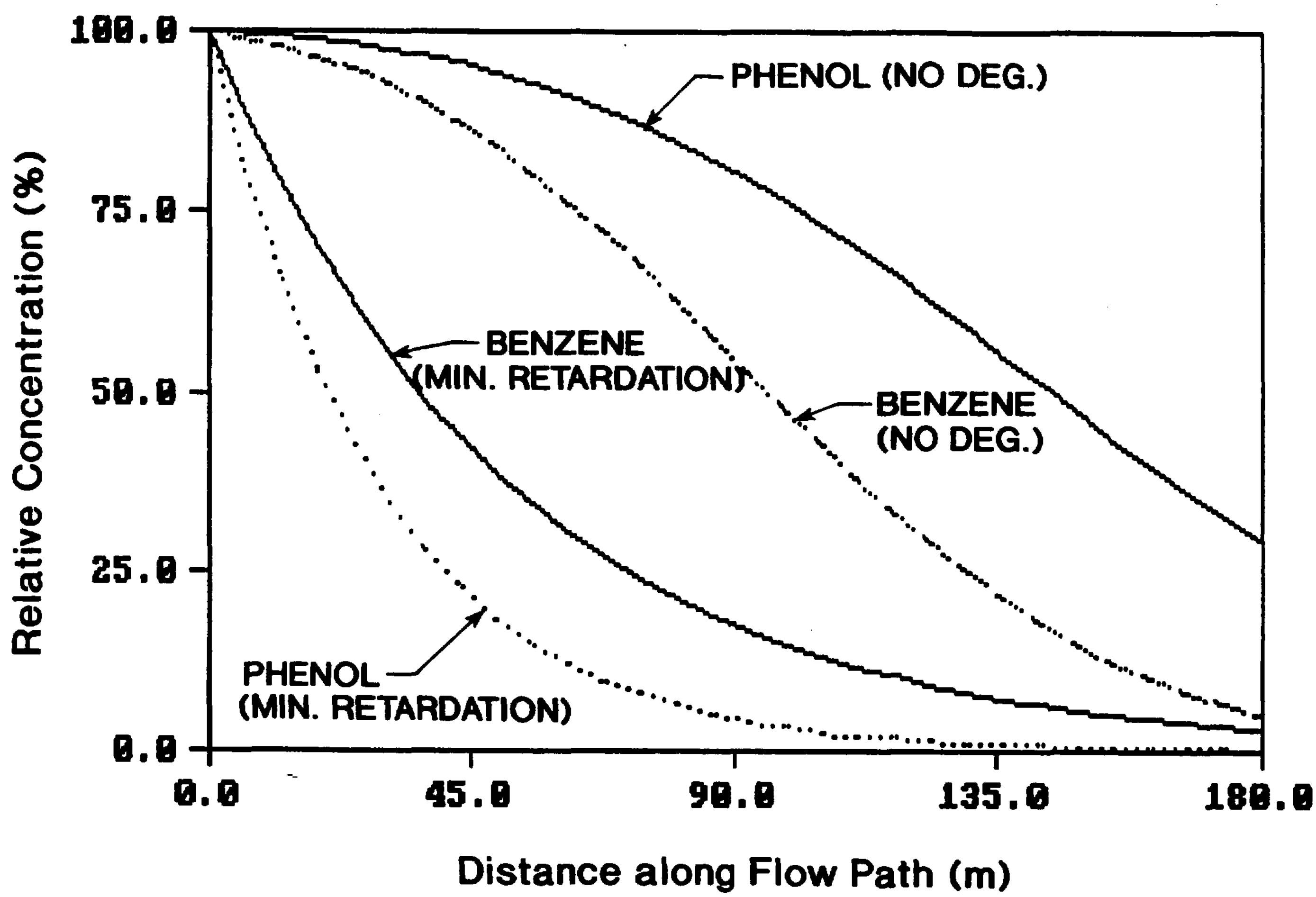

Figure 8-B-5

RESULTS FOR SW FLOW PATH, t = 45 YR.
(Sensitivity Parameters)

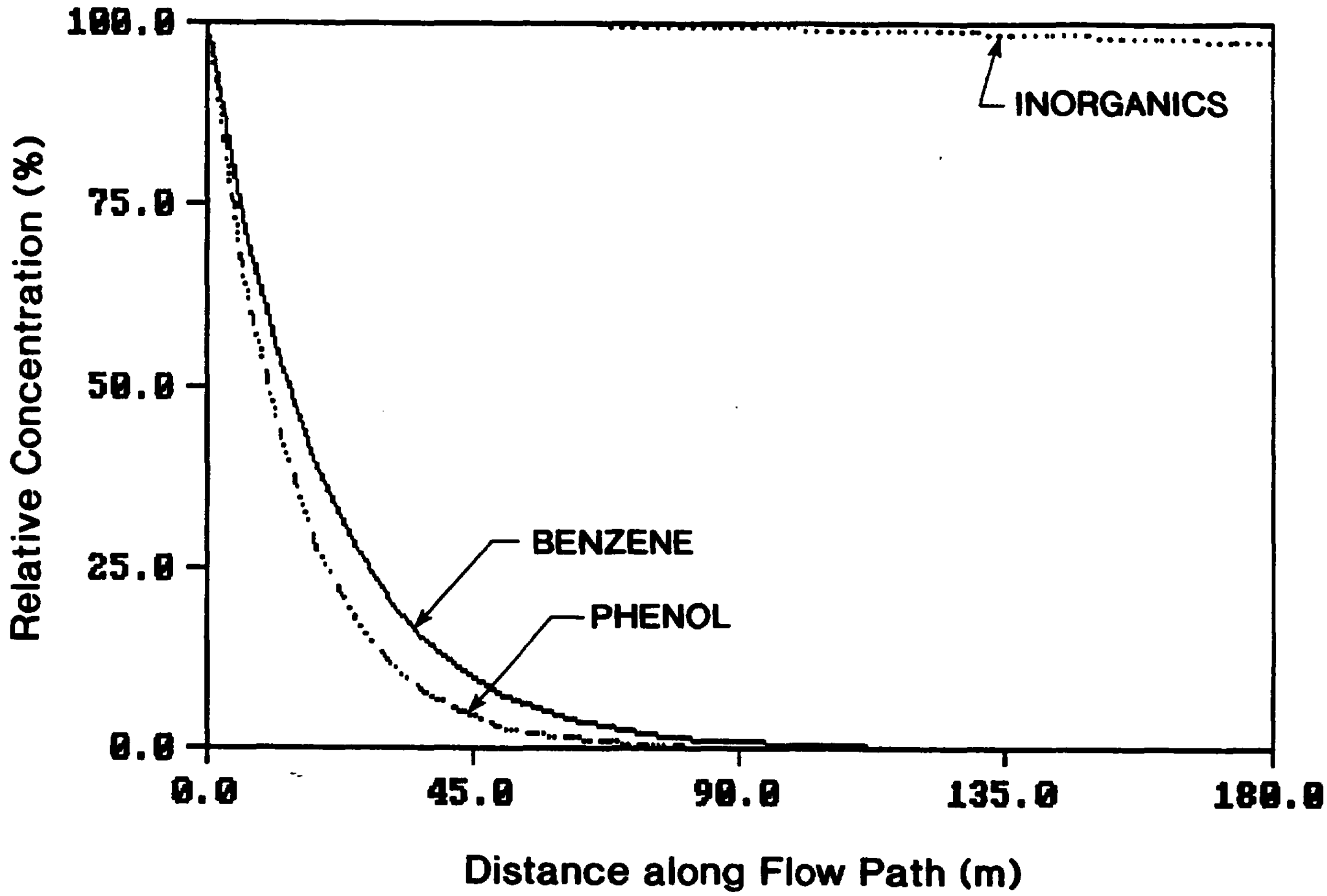

Figure 8-B-6

RESULTS FOR SW FLOW PATH, t = 65 YR.
(Site-Representative Parameters)

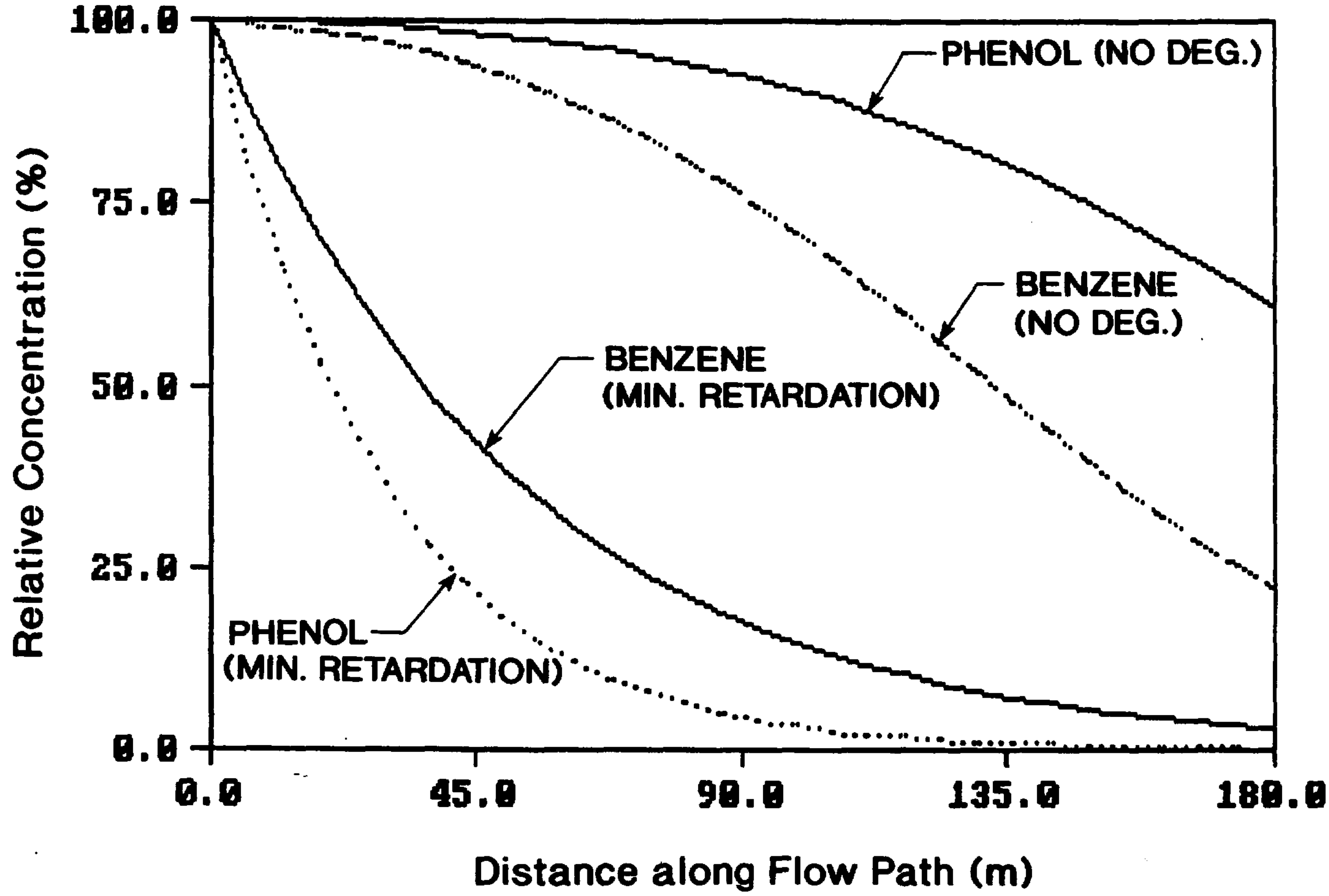

Figure 8-B-7

RESULTS FOR SW FLOW PATH, t = 65 YR.
(Sensitivity Parameters)

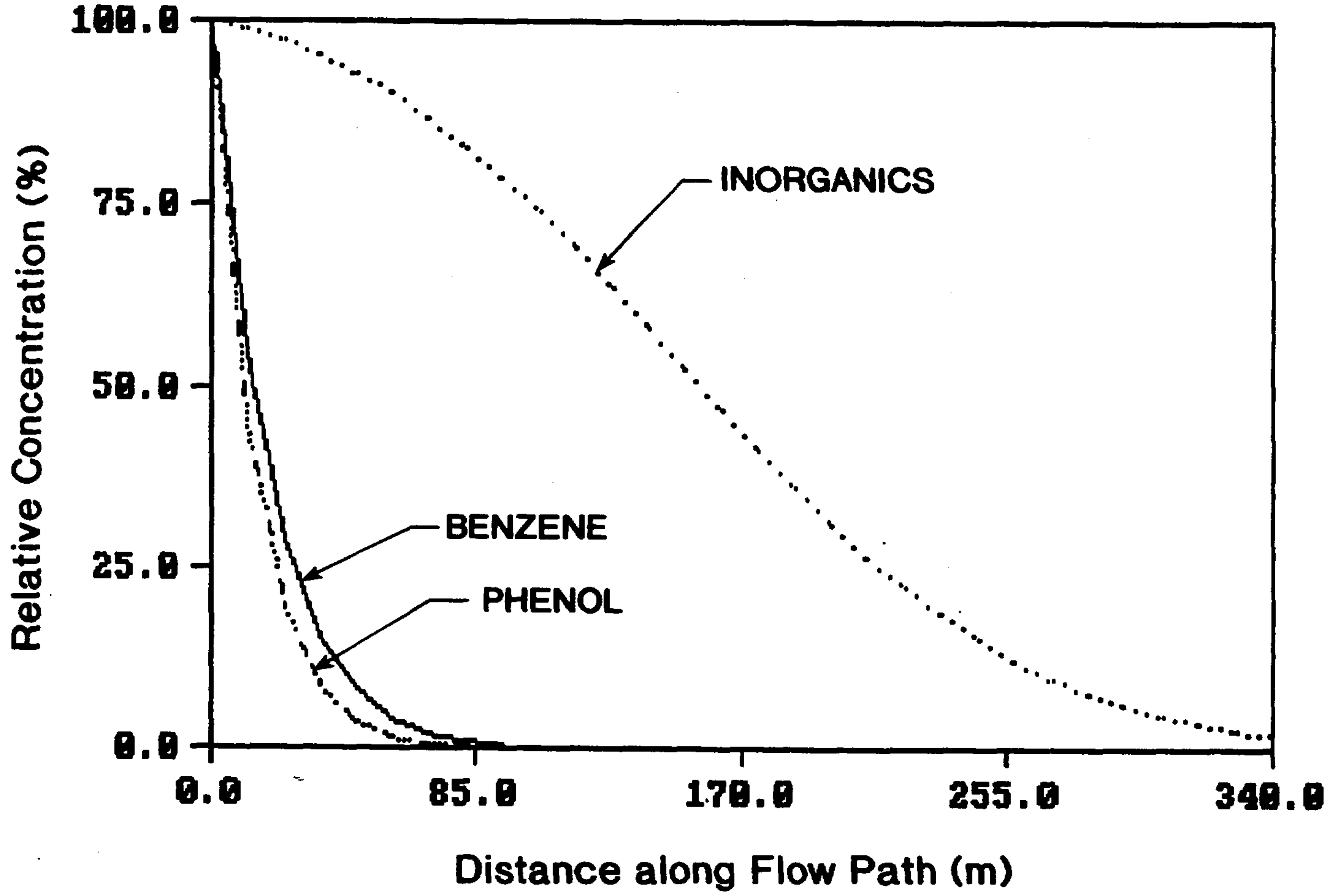

Figure 8-B-8

RESULTS FOR S FLOW PATH, t = 20 YR.
(Site-Representative Parameters)

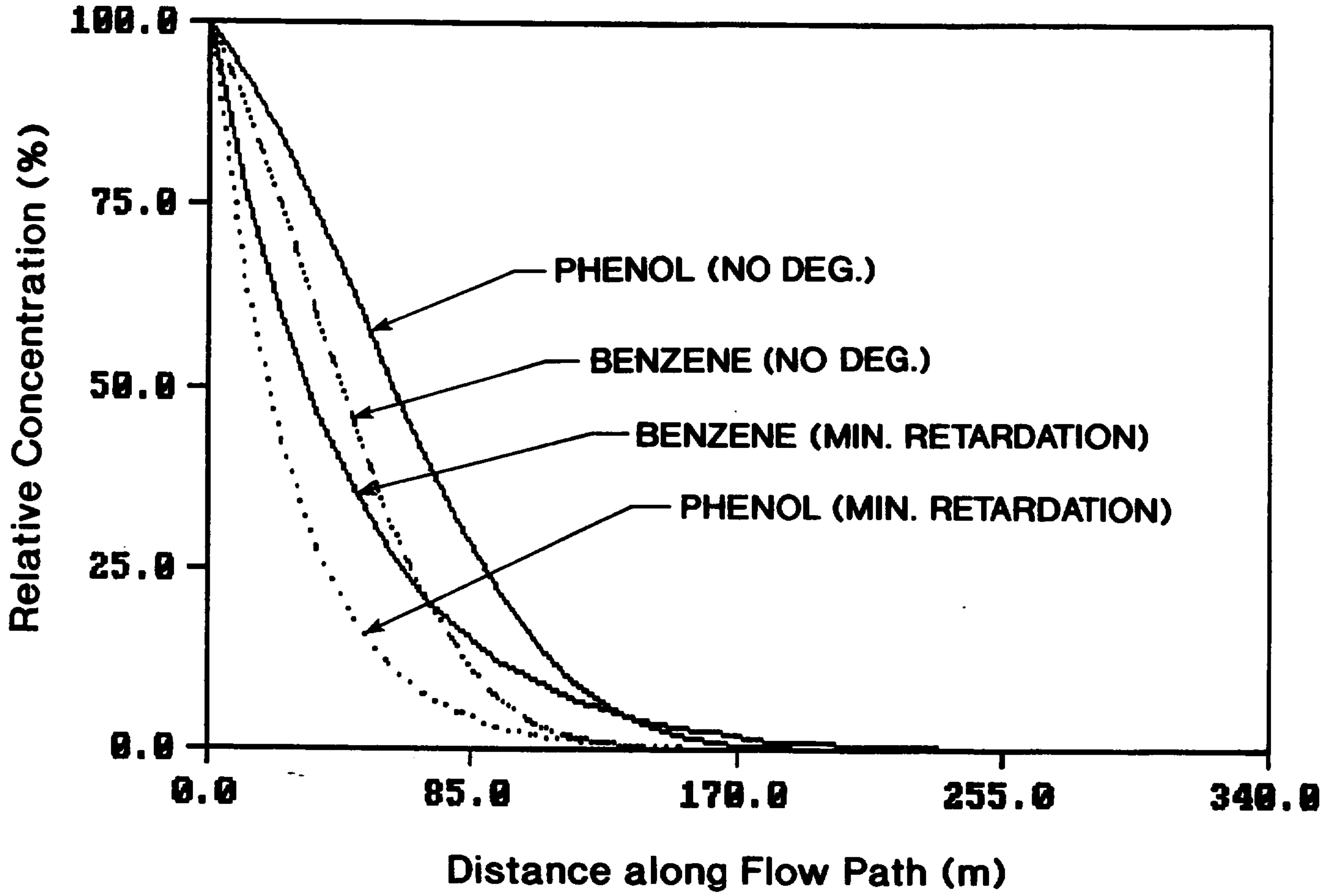

Figure 8-B-9

RESULTS FOR S FLOW PATH, t = 20 YR.
(Sensitivity Parameters)

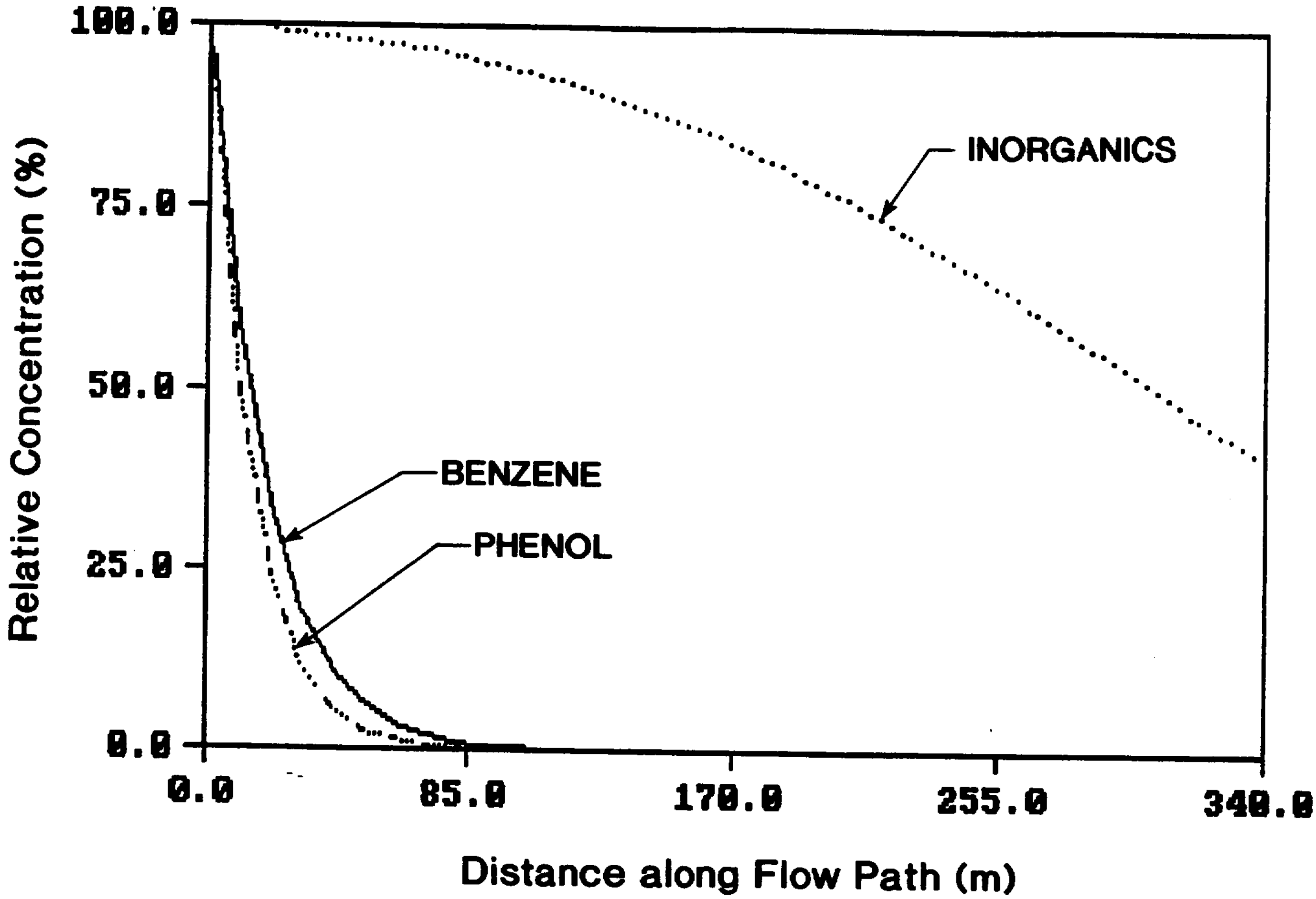

Figure 8-B-10

RESULTS FOR S FLOW PATH, t = 45 YR.
(Site-Representative Parameters)

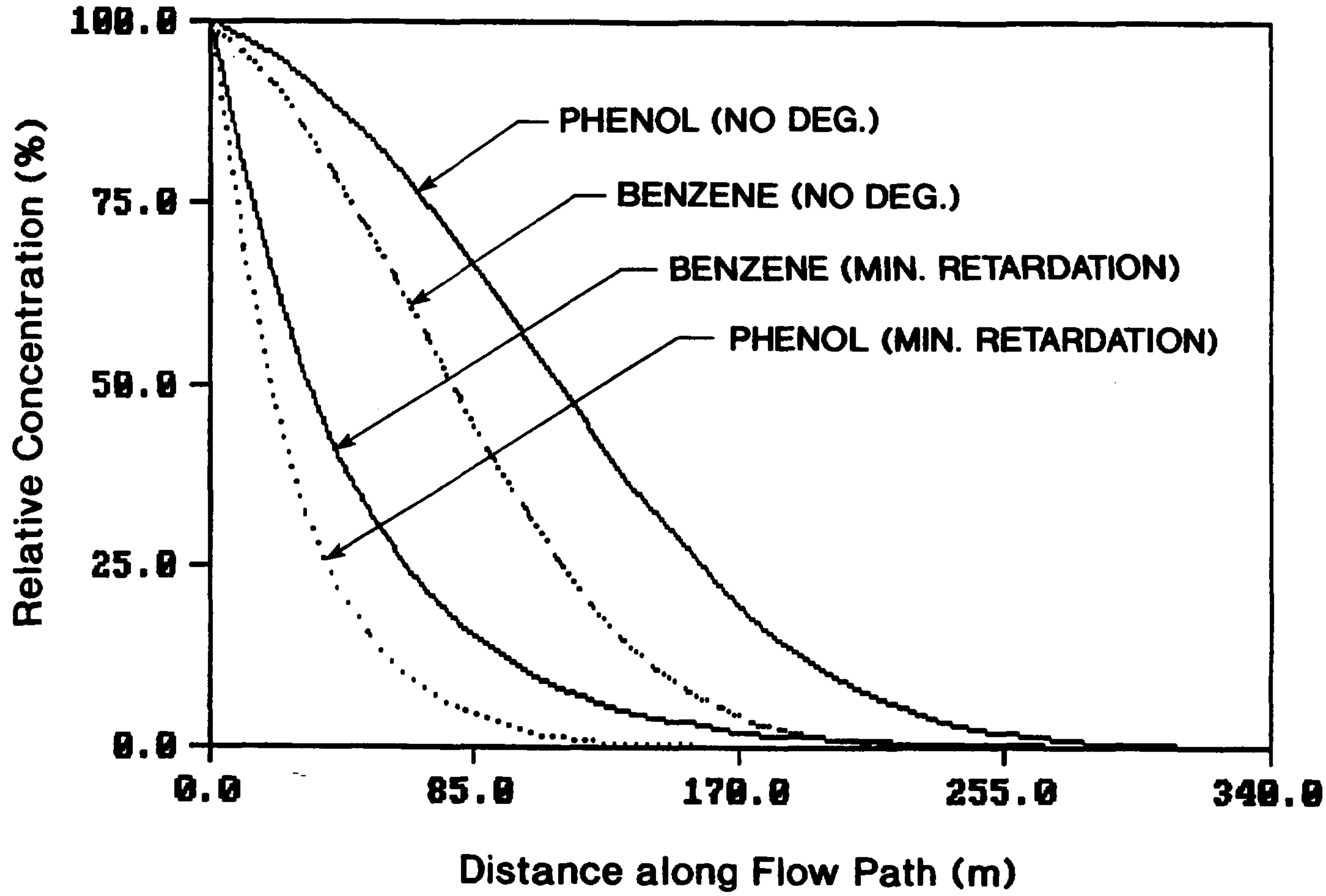

Figure 8-B-11

RESULTS FOR S FLOW PATH, t = 45 YR.
(Sensitivity Parameters)

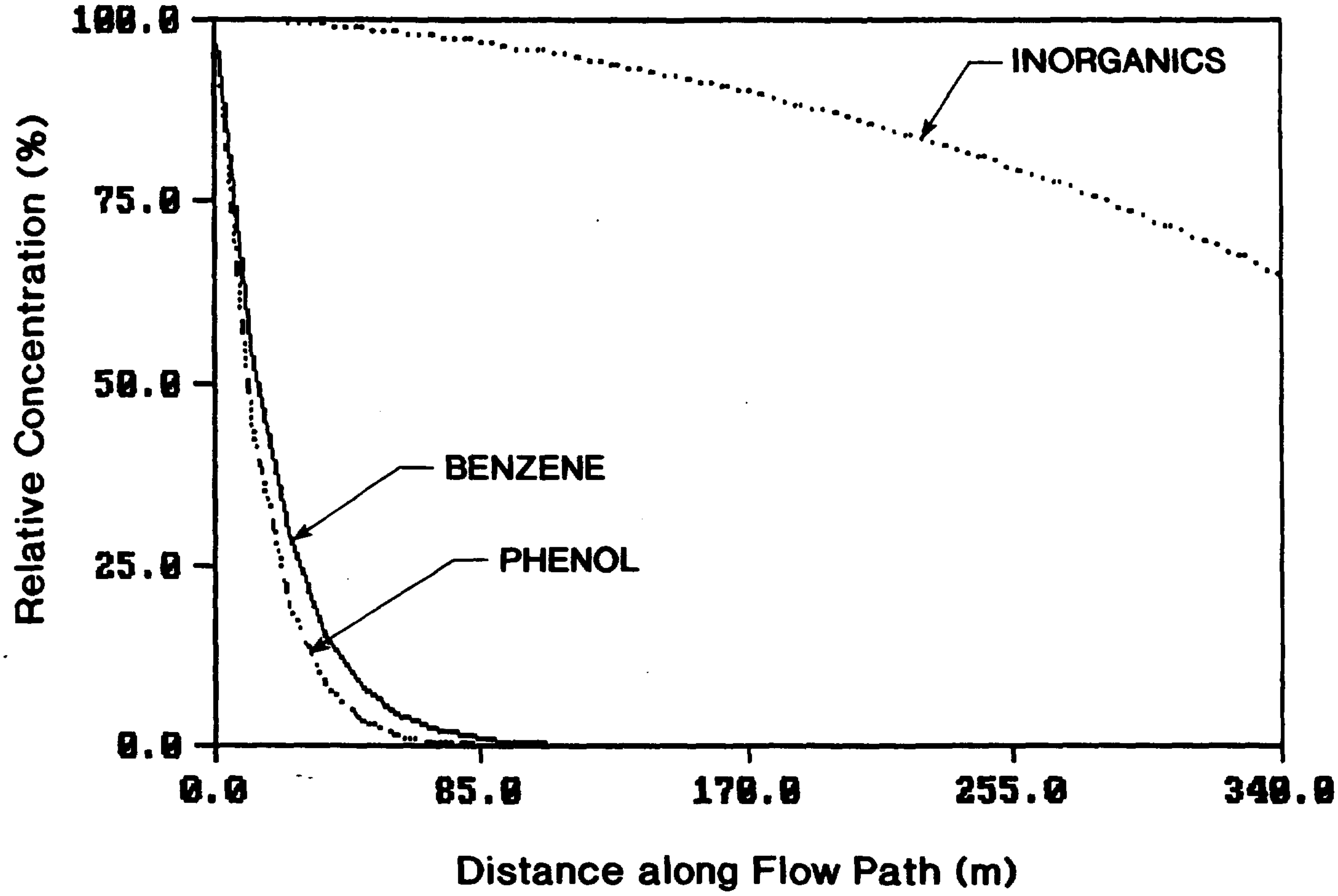

Figure 8-B-12

RESULTS FOR S FLOW PATH, t = 65 YR.
(Site-Representative Parameters)

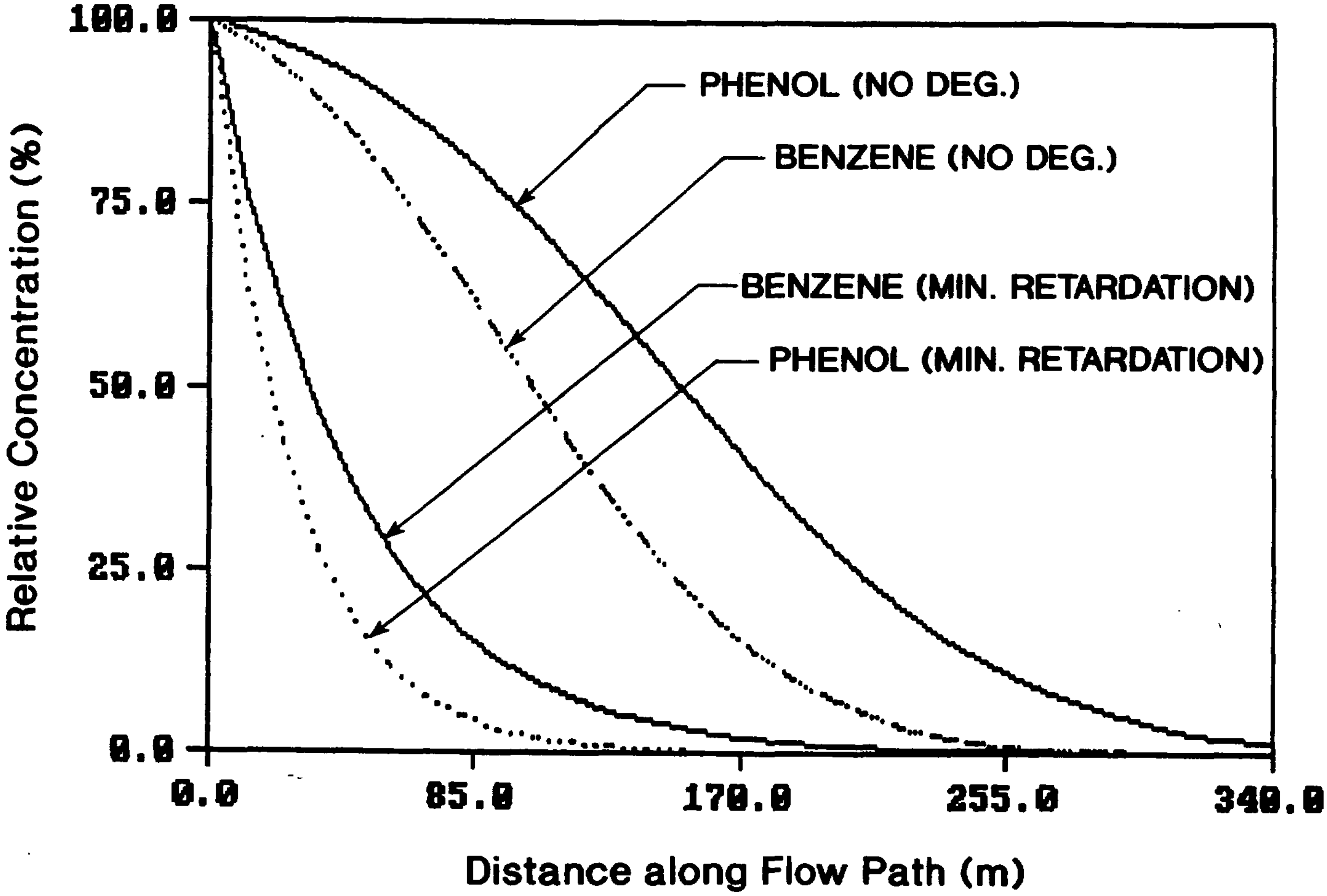

Figure 8-B-13

RESULTS FOR S FLOW PATH, t = 65 YR.
(Sensitivity Parameters)

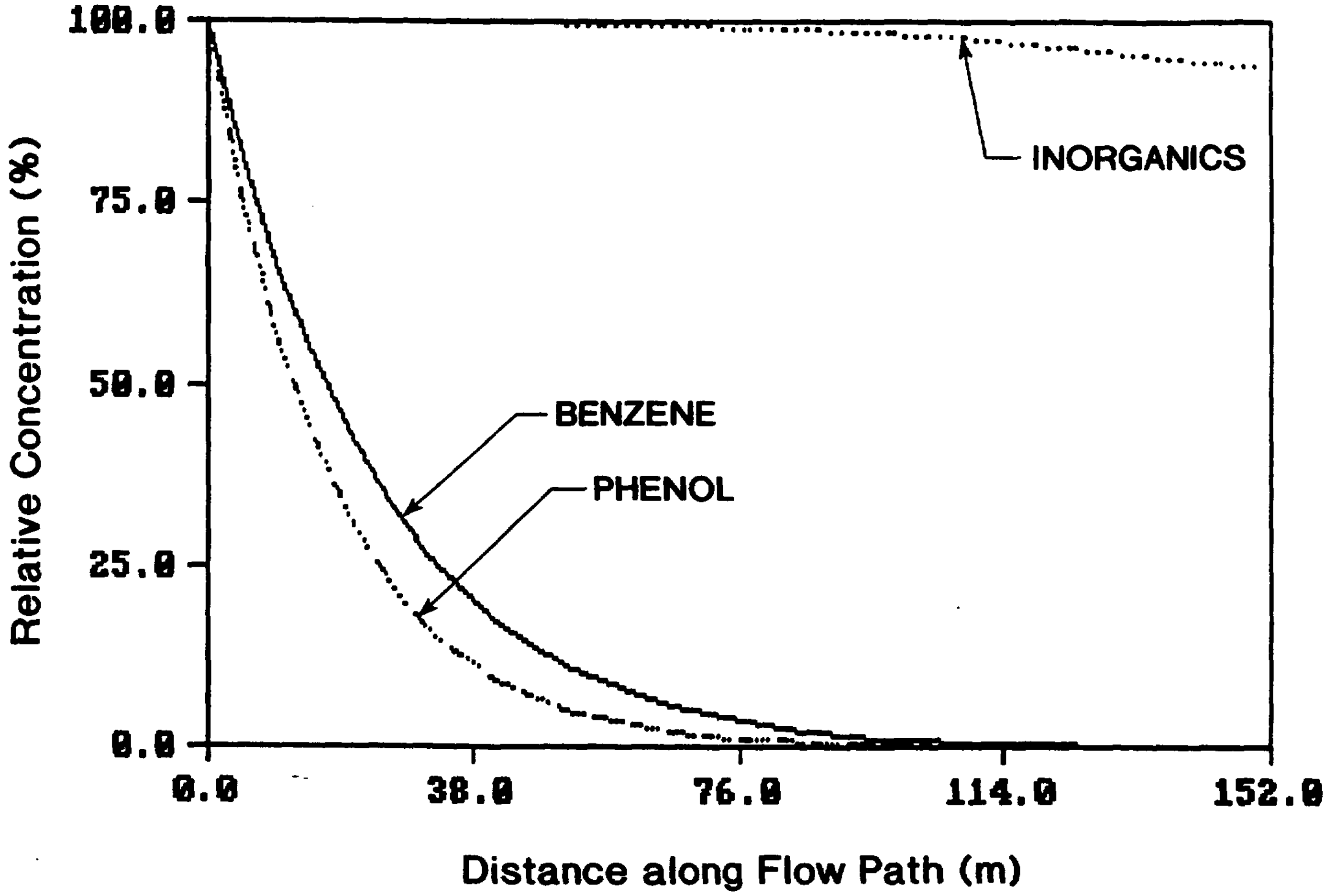

Figure 8-B-14

RESULTS FOR SE FLOW PATH, t = 20 YR.
(Site-Representative Parameters)

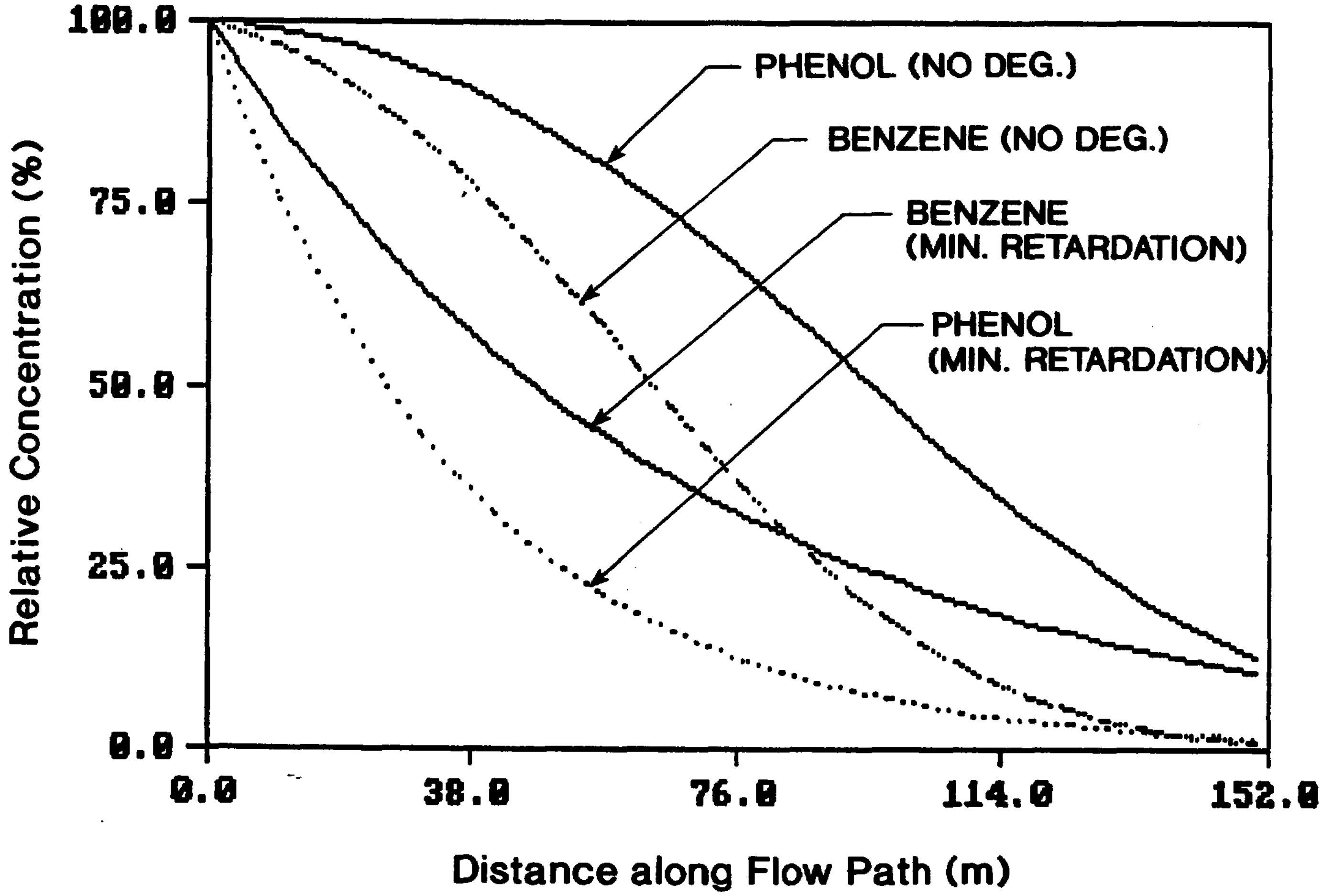

Figure 8-B-15

RESULTS FOR SE FLOW PATH, t = 20 YR.
(Sensitivity Parameters)

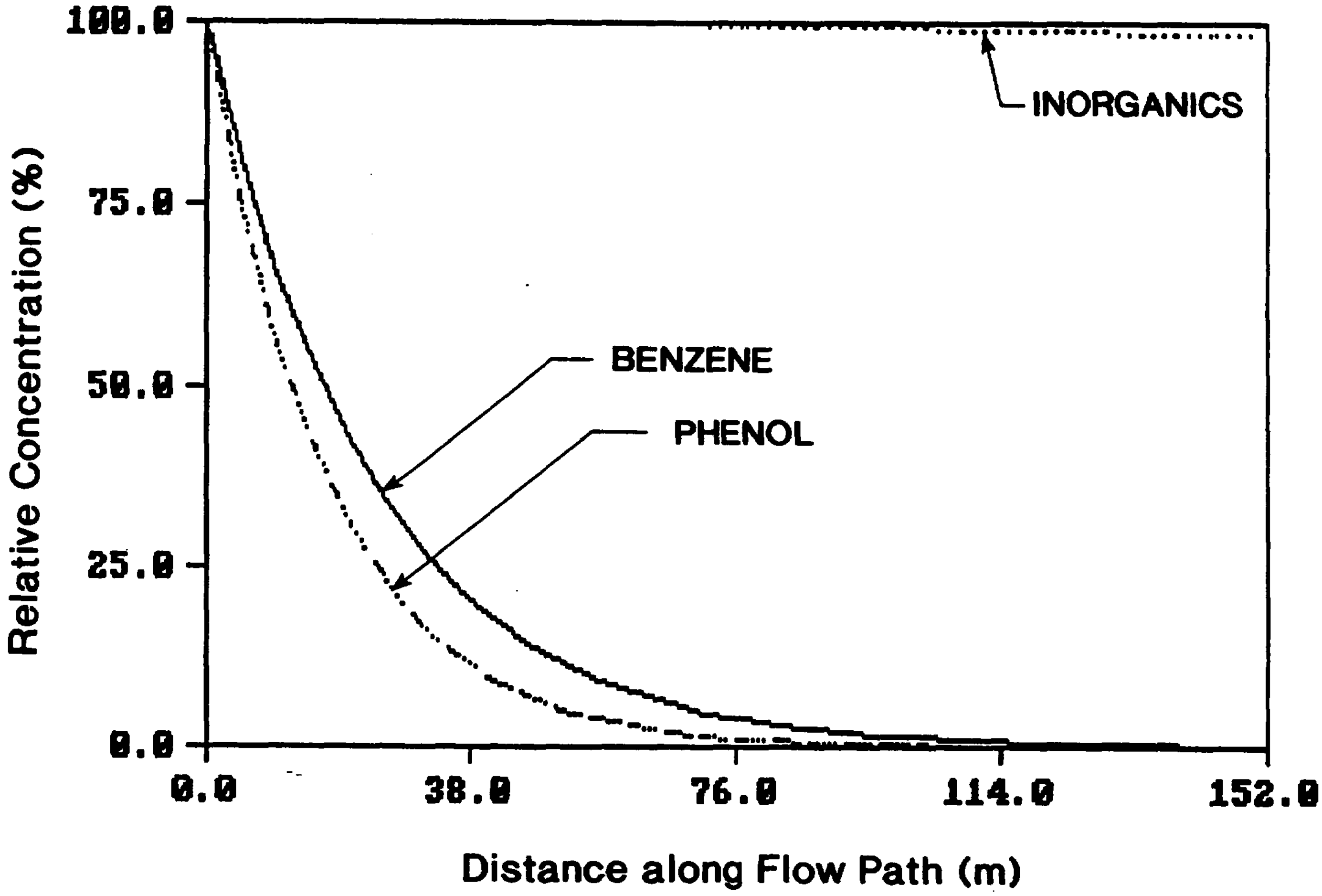

Figure 8-B-16

RESULTS FOR SE FLOW PATH, t = 45 YR.
(Site-Representative Parameters)

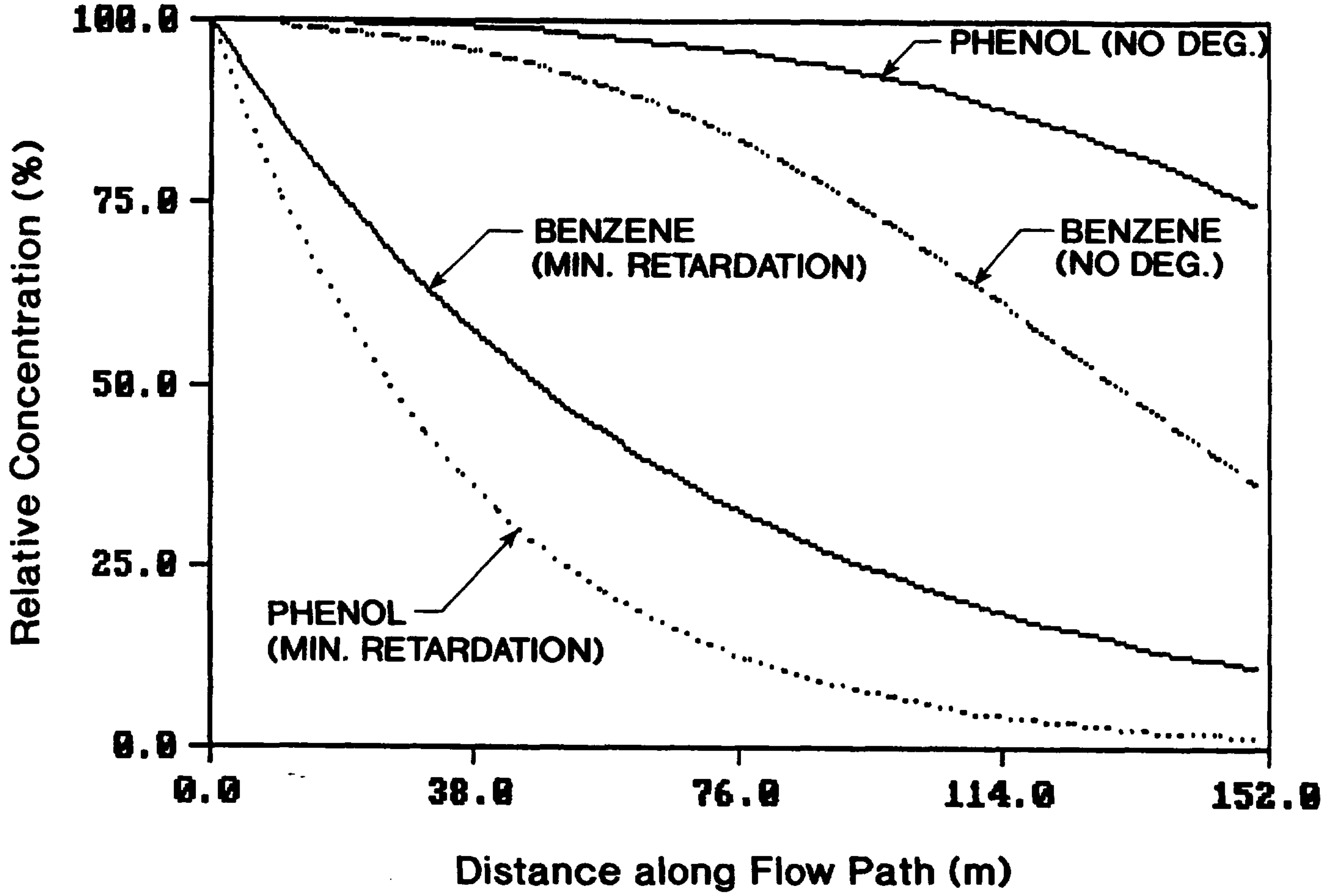

Figure 8-B-17

RESULTS FOR SE FLOW PATH, t = 45 YR.
(Sensitivity Parameters)

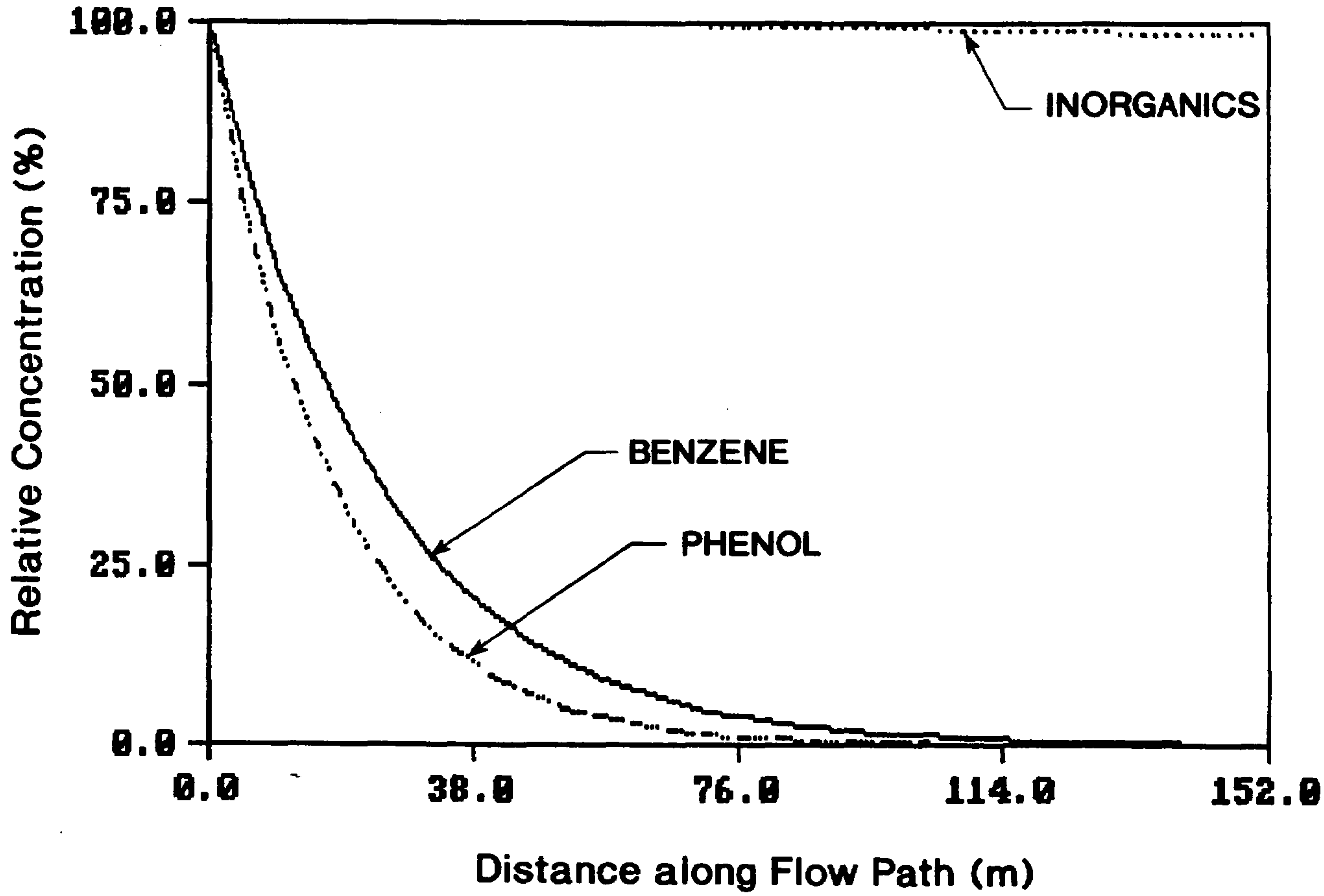

Figure 8-B-18

RESULTS FOR SE FLOW PATH, t = 65 YR.
(Site-Representative Parameters)

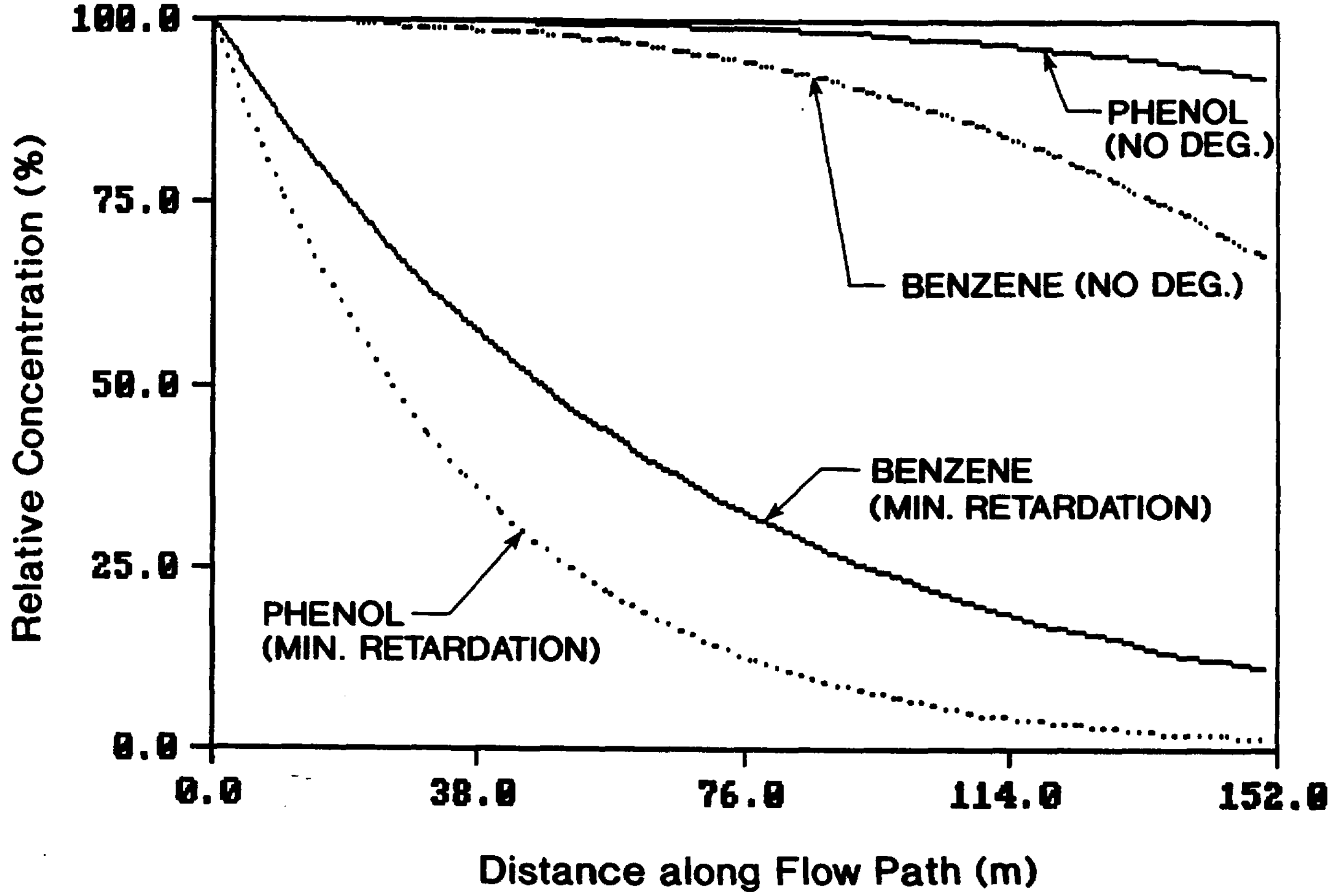

Figure 8-B-19

RESULTS FOR SE FLOW PATH, t = 65 YR.
(Sensitivity Parameters)

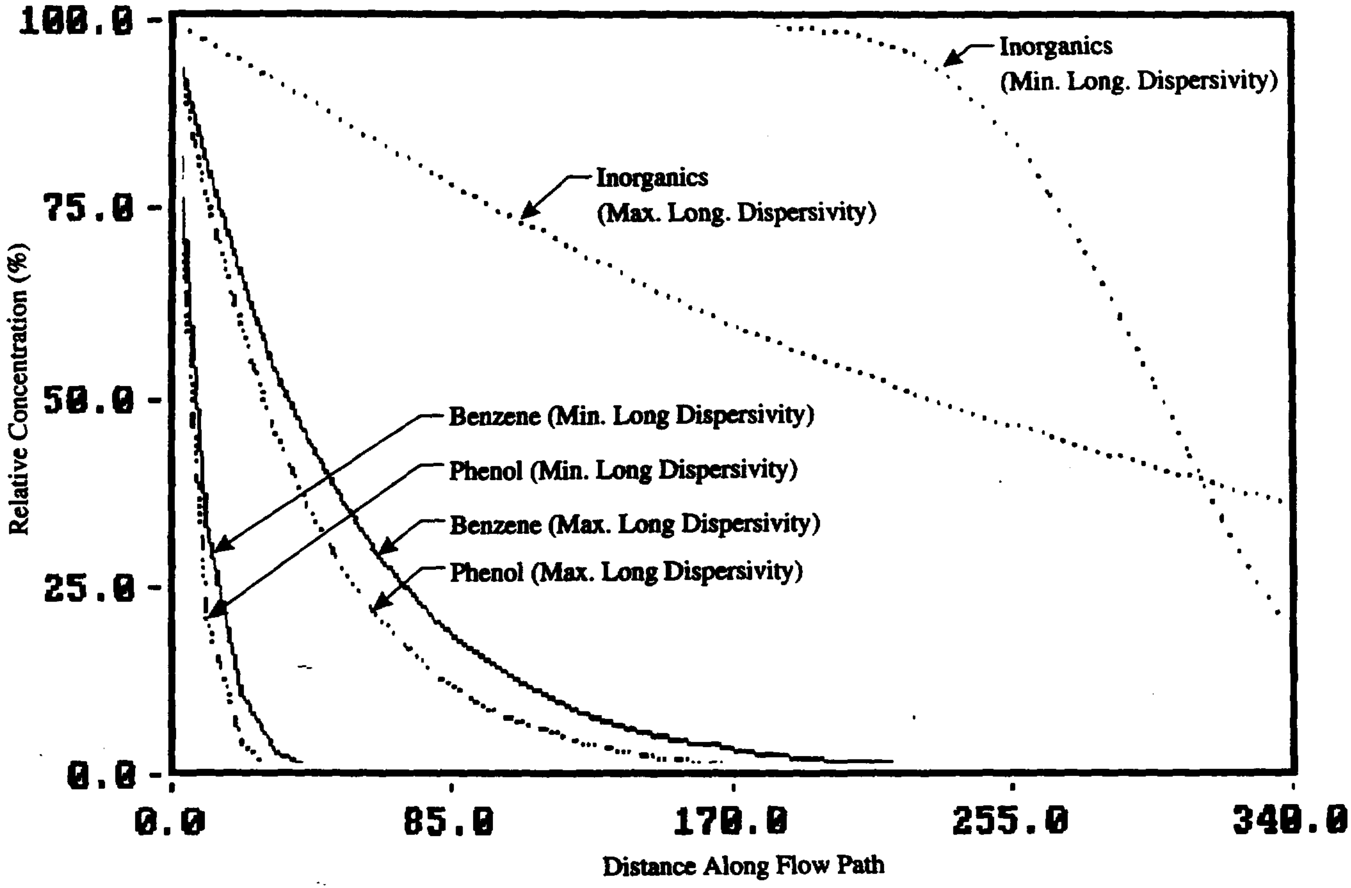

Figure 8-B-20

RESULTS FOR S FLOW PATH, t = 45YR.
(Sensitivity to Longitudinal Dispersivity)

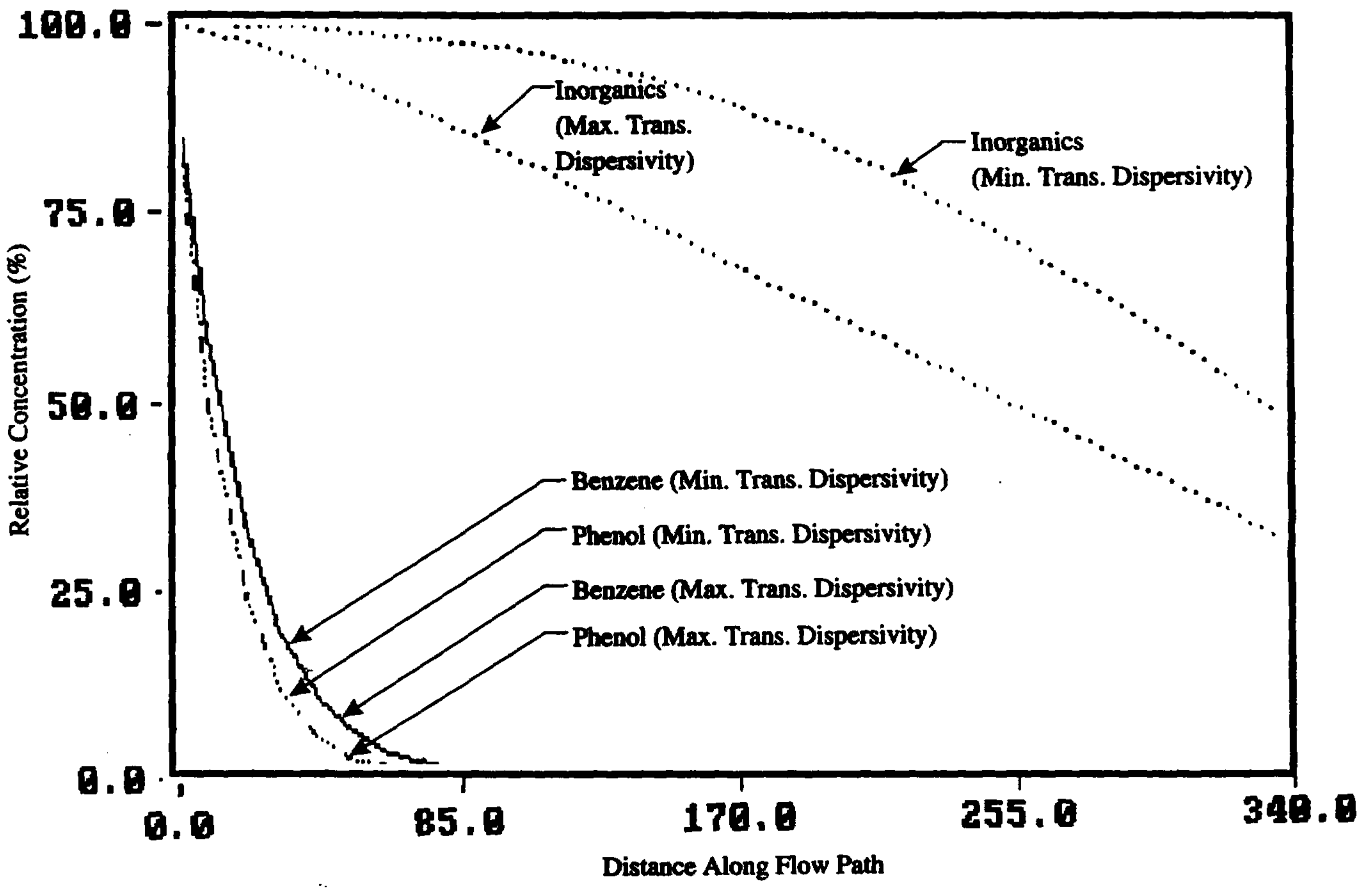

Figure 8-B-21

RESULTS FOR S FLOW PATH, t = 45YR.
(Sensitivity to Transverse Dispersivity)

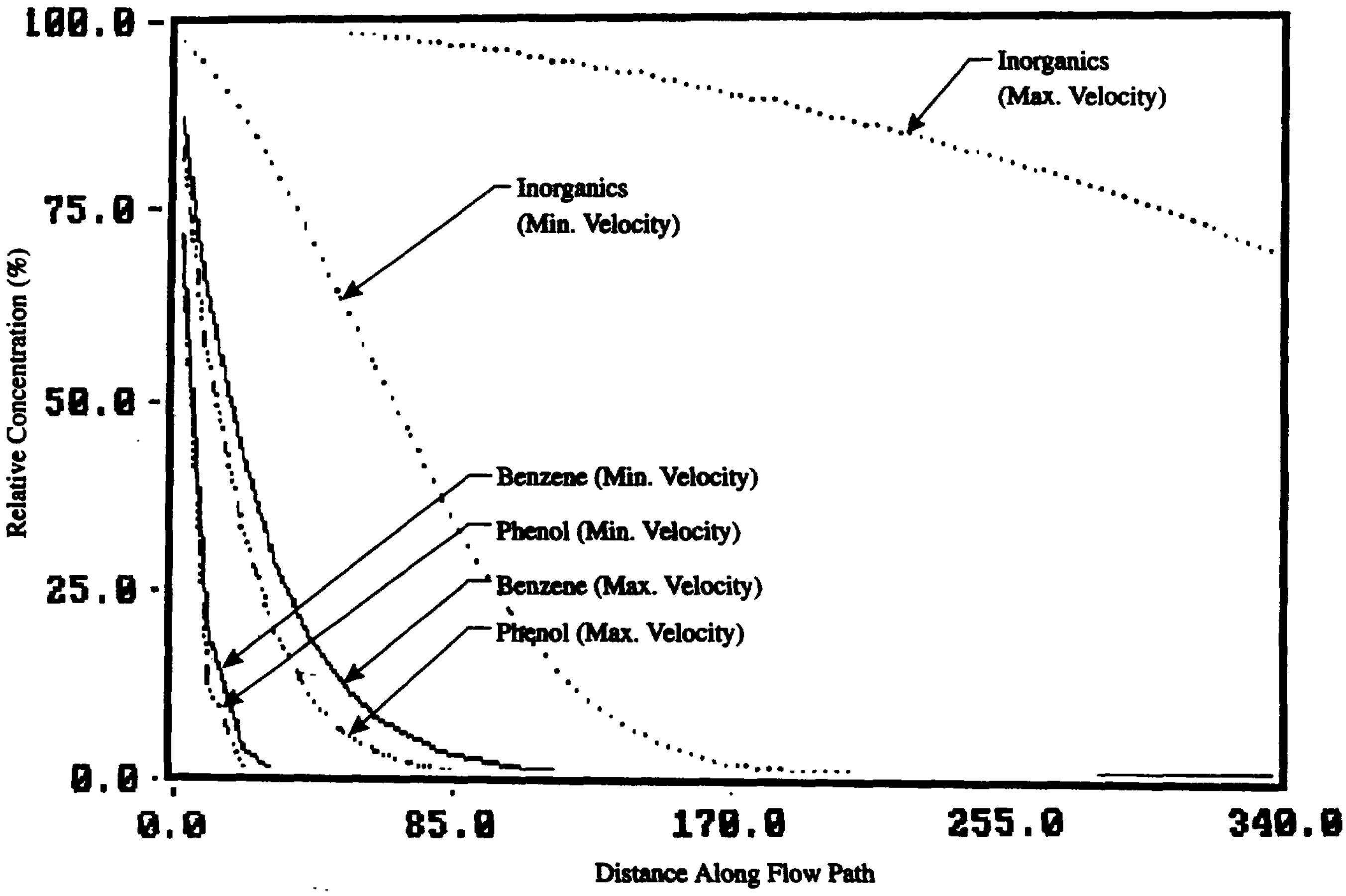

Figure 8-B-22

RESULTS FOR S FLOW PATH, t = 45YR.
(Sensitivity to Groundwater Flow Velocity)

Attachment 8-B-1

MYGRT Version 2.0

Simulation of BASE at WCP SW

Horizontal, Areal Organic Solute

Background Concentration of BASE : Cbk = 0.000000 (ug/L)
Aquifer Concentration of BASE : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	9.7	180	18.0	0	100.0	5.40	0.18000
[illegible]	9.7	180	18.0	0	100.0	3.40	0.45000
B	9.7	180	18.0	0	100.0	1.00	0.00000

Site : WCP SW Simulation : Base

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.462e+001	3.293e+000	1.246e+002	5.719e-002
4.615e+000	7.889e+001	6.923e+001	2.527e+000	1.292e+002	3.900e-002
9.231e+000	6.223e+001	7.385e+001	1.929e+000	1.338e+002	2.627e-002
1.385e+001	4.907e+001	7.846e+001	1.463e+000	1.385e+002	1.747e-002
1.846e+001	3.868e+001	8.308e+001	1.102e+000	1.431e+002	1.147e-002
2.308e+001	3.047e+001	8.769e+001	8.237e-001	1.477e+002	7.436e-003
2.769e+001	2.398e+001	9.231e+001	6.107e-001	1.523e+002	4.756e-003
3.231e+001	1.886e+001	9.692e+001	4.489e-001	1.569e+002	3.001e-003
3.692e+001	1.481e+001	1.015e+002	3.269e-001	1.615e+002	1.868e-003
4.154e+001	1.161e+001	1.062e+002	2.357e-001	1.662e+002	1.146e-003
4.615e+001	9.081e+000	1.108e+002	1.682e-001	1.708e+002	6.939e-00[illegible]
5.077e+001	7.085e+000	1.154e+002	1.187e-001	1.754e+002	4.141e-004
5.538e+001	5.510e+000	1.200e+002	8.288e-002	1.800e+002	2.436e-004
6.000e+001	4.269e+000				

Site : WCP SW   Simulation : A

Concentration vs Distance at T = 20.00 (yr) and Y =

---	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BAS (u
0.0	0.000e+000	1.000e+002	6.462e+001	1.149e+000	1.246e+002	1.7
4.6	4.615e+000	7.269e+001	6.923e+001	8.352e-001	1.292e+002	1.2
9.2	9.231e+000	5.284e+001	7.385e+001	6.069e-001	1.338e+002	9.1
1.3	1.385e+001	3.841e+001	7.846e+001	4.409e-001	1.385e+002	6.5
1.8	1.846e+001	2.792e+001	8.308e+001	3.203e-001	1.431e+002	4.7
2.3	2.308e+001	2.029e+001	8.769e+001	2.326e-001	1.477e+002	3.3
2.7	2.769e+001	1.475e+001	9.231e+001	1.689e-001	1.523e+002	2.3
3.2	3.231e+001	1.072e+001	9.692e+001	1.226e-001	1.569e+002	1.7
3.6	3.692e+001	7.795e+000	1.015e+002	8.890e-002	1.615e+002	1.2
4.1	4.154e+001	5.666e+000	1.062e+002	6.444e-002	1.662e+002	8.5
4.6	4.615e+001	4.118e+000	1.108e+002	4.668e-002	1.708e+002	5.9
5.0	5.077e+001	2.994e+000	1.154e+002	3.378e-002	1.754e+002	4.1
5.5	5.538e+001	2.176e+000	1.200e+002	2.442e-002	1.800e+002	2.9
6.0	6.000e+001	1.581e+000				

MYGRT Version 2.0

Simulation of SENS at WCP SW

Horizontal, Areal Organic Solute

Background Concentration of SENS :	Cbk =	0.000000	(ug/L)
Aquifer Concentration of SENS :	Co =	100.000000	(ug/L)
Source Width:	W =	120.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	9.7	180	18.0	0	100.0	1.40	0.18000
A	9.7	180	18.0	0	100.0	5.40	0.00000
B	9.7	180	18.0	0	100.0	1.20	0.45000
C	9.7	180	18.0	0	100.0	3.40	0.00000

Site : WCP SW Simulation : Base

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	3.035e+001	1.241e+002	8.929e+000
6.207e+000	8.878e+001	6.828e+001	2.692e+001	1.303e+002	7.861e+000
1.241e+001	7.882e+001	7.448e+001	2.387e+001	1.366e+002	6.911e+000
1.862e+001	6.998e+001	8.069e+001	2.116e+001	1.428e+002	6.066e+000
2.483e+001	6.212e+001	8.690e+001	1.874e+001	1.490e+002	5.314e+000
3.103e+001	5.515e+001	9.310e+001	1.660e+001	1.552e+002	4.646e+000
3.724e+001	4.895e+001	9.931e+001	1.469e+001	1.614e+002	4.053e+000
4.345e+001	4.345e+001	1.055e+002	1.299e+001	1.676e+002	3.527e+000
4.966e+001	3.856e+001	1.117e+002	1.148e+001	1.738e+002	3.061e+000
5.586e+001	3.421e+001	1.179e+002	1.013e+001	1.800e+002	2.649e+000

Site : WCP SW   Simulation : A

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	3.402e+001	1.241e+002	1.255e+000
6.207e+000	9.658e+001	6.828e+001	2.734e+001	1.303e+002	7.822e-001
1.241e+001	9.213e+001	7.448e+001	2.146e+001	1.366e+002	4.747e-001
1.862e+001	8.666e+001	8.069e+001	1.644e+001	1.428e+002	2.805e-001
2.483e+001	8.026e+001	8.690e+001	1.229e+001	1.490e+002	1.613e-001
3.103e+001	7.308e+001	9.310e+001	8.964e+000	1.552e+002	9.022e-002
3.724e+001	6.534e+001	9.931e+001	6.372e+000	1.614e+002	4.911e-002
4.345e+001	5.729e+001	1.055e+002	4.414e+000	1.676e+002	2.601e-002
4.966e+001	4.921e+001	1.117e+002	2.980e+000	1.738e+002	1.340e-002
5.586e+001	4.138e+001	1.179e+002	1.959e+000	1.800e+002	6.714e-003

Site : WCP SW   Simulation : C

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	5.932e+001	1.241e+002	1.056e+001
6.207e+000	9.836e+001	6.828e+001	5.316e+001	1.303e+002	8.177e+000
1.241e+001	9.620e+001	7.448e+001	4.703e+001	1.366e+002	6.233e+000
1.862e+001	9.347e+001	8.069e+001	4.105e+001	1.428e+002	4.675e+000
2.483e+001	9.014e+001	8.690e+001	3.534e+001	1.490e+002	3.450e+000
3.103e+001	8.621e+001	9.310e+001	2.999e+001	1.552e+002	2.504e+000
3.724e+001	8.171e+001	9.931e+001	2.509e+001	1.614e+002	1.788e+000
4.345e+001	7.668e+001	1.055e+002	2.067e+001	1.676e+002	1.255e+000
4.966e+001	7.120e+001	1.117e+002	1.678e+001	1.738e+002	8.666e-001
5.586e+001	6.538e+001	1.179e+002	1.341e+001	1.800e+002	5.883e-001

MYGRT Version 2.0

Simulation of BASE at WCP SW

Horizontal, Areal Organic Solute

Background Concentration of BASE : Cbk = 0.000000 (ug/L)
Aquifer Concentration of BASE : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
ıse	9.7	180	18.0	0	100.0	5.40	0.18000
A	9.7	180	18.0	0	100.0	3.40	0.45000
B	9.7	180	18.0	0	100.0	1.00	0.00000

Site : WCP SW Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.207e+001	4.134e+000	1.241e+002	1.686e-001
6.207e+000	7.272e+001	6.828e+001	3.006e+000	1.303e+002	1.220e-001
1.241e+001	5.288e+001	7.448e+001	2.185e+000	1.366e+002	8.817e-002
1.862e+001	3.845e+001	8.069e+001	1.588e+000	1.428e+002	6.361e-002
2.483e+001	2.796e+001	8.690e+001	1.154e+000	1.490e+002	4.580e-002
3.103e+001	2.033e+001	9.310e+001	8.387e-001	1.552e+002	3.290e-002
3.724e+001	1.479e+001	9.931e+001	6.092e-001	1.614e+002	2.357e-002
4.345e+001	1.075e+001	1.055e+002	4.423e-001	1.676e+002	1.683e-002
4.966e+001	7.819e+000	1.117e+002	3.210e-001	1.738e+002	1.197e-002
5.586e+001	5.685e+000	1.179e+002	2.327e-001	1.800e+002	8.487e-003

Site : WCP SW   Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.207e+001	1.371e+000	1.241e+002	1.880e-002
6.207e+000	6.512e+001	6.828e+001	8.930e-001	1.303e+002	1.224e-002
1.241e+001	4.241e+001	7.448e+001	5.815e-001	1.366e+002	7.974e-003
1.862e+001	2.761e+001	8.069e+001	3.787e-001	1.428e+002	5.192e-003
2.483e+001	1.798e+001	8.690e+001	2.466e-001	1.490e+002	3.381e-003
3.103e+001	1.171e+001	9.310e+001	1.606e-001	1.552e+002	2.202e-003
3.724e+001	7.626e+000	9.931e+001	1.046e-001	1.614e+002	1.434e-003
4.345e+001	4.966e+000	1.055e+002	6.809e-002	1.676e+002	9.337e-004
4.966e+001	3.234e+000	1.117e+002	4.434e-002	1.738e+002	6.080e-004
5.586e+001	2.106e+000	1.179e+002	2.888e-002	1.800e+002	3.959e-004

Site : WCP SW Simulation : B

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.207e+001	9.974e+001	1.241e+002	9.866e+001
6.207e+000	9.999e+001	6.828e+001	9.968e+001	1.303e+002	9.848e+001
1.241e+001	9.998e+001	7.448e+001	9.961e+001	1.366e+002	9.829e+001
1.862e+001	9.997e+001	8.069e+001	9.953e+001	1.428e+002	9.808e+001
2.483e+001	9.995e+001	8.690e+001	9.944e+001	1.490e+002	9.786e+001
3.103e+001	9.993e+001	9.310e+001	9.934e+001	1.552e+002	9.761e+001
3.724e+001	9.990e+001	9.931e+001	9.923e+001	1.614e+002	9.735e+001
4.345e+001	9.987e+001	1.055e+002	9.911e+001	1.676e+002	9.707e+001
4.966e+001	9.983e+001	1.117e+002	9.897e+001	1.738e+002	9.677e+001
5.586e+001	9.979e+001	1.179e+002	9.882e+001	1.800e+002	9.644e+001

MYGRT Version 2.0

Simulation of SENS at WCP SW

Horizontal, Areal Organic Solute

Background Concentration of SENS :	Cbk =	0.000000	(ug/L)
Aquifer Concentration of SENS :	Co =	100.000000	(ug/L)
Source Width:	W =	120.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
se	9.7	180	18.0	0	100.0	1.40	0.18000
A	9.7	180	18.0	0	100.0	5.40	0.00000
B	9.7	180	18.0	0	100.0	1.20	0.45000
C	9.7	180	18.0	0	100.0	3.40	0.00000

Site : WCP SW Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	3.043e+001	1.241e+002	9.252e+000
6.207e+000	8.879e+001	6.828e+001	2.702e+001	1.303e+002	8.213e+000
1.241e+001	7.883e+001	7.448e+001	2.399e+001	1.366e+002	7.290e+000
1.862e+001	6.999e+001	8.069e+001	2.130e+001	1.428e+002	6.470e+000
2.483e+001	6.214e+001	8.690e+001	1.891e+001	1.490e+002	5.743e+000
3.103e+001	5.517e+001	9.310e+001	1.678e+001	1.552e+002	5.097e+000
3.724e+001	4.898e+001	9.931e+001	1.490e+001	1.614e+002	4.523e+000
4.345e+001	4.349e+001	1.055e+002	1.323e+001	1.676e+002	4.014e+000
4.966e+001	3.861e+001	1.117e+002	1.174e+001	1.738e+002	3.562e+000
5.586e+001	3.428e+001	1.179e+002	1.042e+001	1.800e+002	3.161e+000

Site : WCP SW   Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	7.627e+001	1.241e+002	2.879e+001
6.207e+000	9.917e+001	6.828e+001	7.190e+001	1.303e+002	2.478e+001
1.241e+001	9.807e+001	7.448e+001	6.727e+001	1.366e+002	2.111e+001
1.862e+001	9.666e+001	8.069e+001	6.243e+001	1.428e+002	1.780e+001
2.483e+001	9.491e+001	8.690e+001	5.746e+001	1.490e+002	1.484e+001
3.103e+001	9.278e+001	9.310e+001	5.242e+001	1.552e+002	1.225e+001
3.724e+001	9.026e+001	9.931e+001	4.740e+001	1.614e+002	9.991e+000
4.345e+001	8.735e+001	1.055e+002	4.246e+001	1.676e+002	8.061e+000
4.966e+001	8.403e+001	1.117e+002	3.767e+001	1.738e+002	6.431e+000
5.586e+001	8.033e+001	1.179e+002	3.310e+001	1.800e+002	5.072e+000

Site : WCP SW   Simulation : B

Concentration vs Distance at T =   45.00 (yr) and Y =   0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	1.205e+001	1.241e+002	1.451e+000
6.207e+000	8.093e+001	6.828e+001	9.749e+000	1.303e+002	1.174e+000
1.241e+001	6.549e+001	7.448e+001	7.890e+000	1.366e+002	9.501e-001
1.862e+001	5.300e+001	8.069e+001	6.385e+000	1.428e+002	7.689e-001
2.483e+001	4.289e+001	8.690e+001	5.167e+000	1.490e+002	6.222e-001
3.103e+001	3.471e+001	9.310e+001	4.181e+000	1.552e+002	5.034e-001
3.724e+001	2.809e+001	9.931e+001	3.384e+000	1.614e+002	4.074e-001
4.345e+001	2.273e+001	1.055e+002	2.738e+000	1.676e+002	3.296e-001
4.966e+001	1.840e+001	1.117e+002	2.216e+000	1.738e+002	

Solute = SENS

T =
Y =

					2.667e-001
5.586e+001	1.489e+001	1.179e+002	1.793e+000	1.800e+002	2.158e-001

Site : WCP SW Simulation : C

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	9.135e+001	1.241e+002	6.257e+001
6.207e+000	9.974e+001	6.828e+001	8.945e+001	1.303e+002	5.878e+001
1.241e+001	9.939e+001	7.448e+001	8.732e+001	1.366e+002	5.493e+001
1.862e+001	9.893e+001	8.069e+001	8.496e+001	1.428e+002	5.105e+001
2.483e+001	9.835e+001	8.690e+001	8.236e+001	1.490e+002	4.718e+001
3.103e+001	9.763e+001	9.310e+001	7.954e+001	1.552e+002	4.336e+001
3.724e+001	9.676e+001	9.931e+001	7.650e+001	1.614e+002	3.961e+001
4.345e+001	9.571e+001	1.055e+002	7.326e+001	1.676e+002	3.597e+001
4.966e+001	9.446e+001	1.117e+002	6.984e+001	1.738e+002	3.246e+001
5.586e+001	9.301e+001	1.179e+002	6.627e+001	1.800e+002	2.911e+001

MYGRT Version 2.0

Simulation of BASE at WCP SW

Horizontal, Areal Organic Solute

Background Concentration of BASE :	Cbk =	0.000000	(ug/L)
Aquifer Concentration of BASE :	Co =	100.000000	(ug/L)
Source Width:	W =	120.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
se	9.7	180	18.0	0	100.0	5.40	0.18000
A	9.7	180	18.0	0	100.0	3.40	0.45000
B	9.7	180	18.0	0	100.0	1.00	0.00000

Site : WCP SW   Simulation : Base

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.207e+001	4.135e+000	1.241e+002	1.709e-001
6.207e+000	7.272e+001	6.828e+001	3.007e+000	1.303e+002	1.243e-001
1.241e+001	5.288e+001	7.448e+001	2.187e+000	1.366e+002	9.037e-002
1.862e+001	3.845e+001	8.069e+001	1.590e+000	1.428e+002	6.570e-002
2.483e+001	2.796e+001	8.690e+001	1.156e+000	1.490e+002	4.776e-002
3.103e+001	2.034e+001	9.310e+001	8.408e-001	1.552e+002	3.471e-002
3.724e+001	1.479e+001	9.931e+001	6.114e-001	1.614e+002	2.523e-002
4.345e+001	1.075e+001	1.055e+002	4.446e-001	1.676e+002	1.833e-002
4.966e+001	7.820e+000	1.117e+002	3.233e-001	1.738e+002	1.332e-002
5.586e+001	5.686e+000	1.179e+002	2.351e-001	1.800e+002	9.671e-003

Site : WCP SW Simulation : A

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.207e+001	1.371e+000	1.241e+002	1.880e-002
6.207e+000	6.512e+001	6.828e+001	8.930e-001	1.303e+002	1.224e-002
1.241e+001	4.241e+001	7.448e+001	5.815e-001	1.366e+002	7.974e-003
1.862e+001	2.761e+001	8.069e+001	3.787e-001	1.428e+002	5.192e-003
2.483e+001	1.798e+001	8.690e+001	2.466e-001	1.490e+002	3.381e-003
3.103e+001	1.171e+001	9.310e+001	1.606e-001	1.552e+002	2.202e-003
3.724e+001	7.626e+000	9.931e+001	1.046e-001	1.614e+002	1.434e-003
4.345e+001	4.966e+000	1.055e+002	6.809e-002	1.676e+002	9.337e-004
4.966e+001	3.234e+000	1.117e+002	4.434e-002	1.738e+002	6.080e-004
5.586e+001	2.106e+000	1.179e+002	2.888e-002	1.800e+002	3.959e-004

Site : WCP SW Simulation : B

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	6.207e+001	9.977e+001	1.241e+002	9.888e+001
6.207e+000	9.999e+001	6.828e+001	9.971e+001	1.303e+002	9.875e+001
1.241e+001	9.998e+001	7.448e+001	9.965e+001	1.366e+002	9.860e+001
1.862e+001	9.997e+001	8.069e+001	9.959e+001	1.428e+002	9.845e+001
2.483e+001	9.996e+001	8.690e+001	9.951e+001	1.490e+002	9.829e+001
3.103e+001	9.994e+001	9.310e+001	9.943e+001	1.552e+002	9.812e+001
3.724e+001	9.991e+001	9.931e+001	9.934e+001	1.614e+002	9.794e+001
4.345e+001	9.989e+001	1.055e+002	9.924e+001	1.676e+002	9.776e+001
4.966e+001	9.985e+001	1.117e+002	9.913e+001	1.738e+002	9.756e+001
5.586e+001	9.981e+001	1.179e+002	9.901e+001	1.800e+002	9.736e+001

MYGRT Version 2.0

Simulation of SENS at WCP SW

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/L)
Aquifer Concentration of SENS : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	9.7	180	18.0	0	100.0	1.40	0.18000
A	9.7	180	18.0	0	100.0	5.40	0.00000
B	9.7	180	18.0	0	100.0	1.20	0.45000
C	9.7	180	18.0	0	100.0	3.40	0.00000

Site : WCP SW Simulation : Base

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	3.043e+001	1.241e+002	9.253e+000
6.207e+000	8.879e+001	6.828e+001	2.702e+001	1.303e+002	8.213e+000
1.241e+001	7.883e+001	7.448e+001	2.399e+001	1.366e+002	7.290e+000
1.862e+001	6.999e+001	8.069e+001	2.130e+001	1.428e+002	6.471e+000
2.483e+001	6.214e+001	8.690e+001	1.891e+001	1.490e+002	5.743e+000
3.103e+001	5.517e+001	9.310e+001	1.678e+001	1.552e+002	5.097e+000
3.724e+001	4.898e+001	9.931e+001	1.490e+001	1.614e+002	4.524e+000
4.345e+001	4.349e+001	1.055e+002	1.323e+001	1.676e+002	4.015e+000
4.966e+001	3.861e+001	1.117e+002	1.174e+001	1.738e+002	3.563e+000
5.586e+001	3.428e+001	1.179e+002	1.042e+001	1.800e+002	3.162e+000

Site : WCP SW   Simulation : A

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	8.902e+001	1.241e+002	5.564e+001
6.207e+000	9.966e+001	6.828e+001	8.669e+001	1.303e+002	5.156e+001
1.241e+001	9.921e+001	7.448e+001	8.409e+001	1.366e+002	4.747e+001
1.862e+001	9.861e+001	8.069e+001	8.124e+001	1.428e+002	4.344e+001
2.483e+001	9.787e+001	8.690e+001	7.813e+001	1.490e+002	3.949e+001
3.103e+001	9.694e+001	9.310e+001	7.480e+001	1.552e+002	3.566e+001
3.724e+001	9.582e+001	9.931e+001	7.127e+001	1.614e+002	3.199e+001
4.345e+001	9.448e+001	1.055e+002	6.755e+001	1.676e+002	2.849e+001
4.966e+001	9.291e+001	1.117e+002	6.368e+001	1.738e+002	2.520e+001
5.586e+001	9.110e+001	1.179e+002	5.970e+001	1.800e+002	2.214e+001

Site : WCP SW   Simulation : B

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	1.205e+001	1.241e+002	1.451e+000
6.207e+000	8.093e+001	6.828e+001	9.749e+000	1.303e+002	1.174e+000
1.241e+001	6.549e+001	7.448e+001	7.890e+000	1.366e+002	9.501e-001
1.862e+001	5.300e+001	8.069e+001	6.385e+000	1.428e+002	7.689e-001
2.483e+001	4.289e+001	8.690e+001	5.167e+000	1.490e+002	6.222e-001
3.103e+001	3.471e+001	9.310e+001	4.181e+000	1.552e+002	5.034e-001
3.724e+001	2.809e+001	9.931e+001	3.384e+000	1.614e+002	4.074e-001
4.345e+001	2.273e+001	1.055e+002	2.738e+000	1.676e+002	3.296e-001
4.966e+001	1.840e+001	1.117e+002	2.216e+000	1.738e+002	2.667e-001
5.586e+001	1.489e+001	1.179e+002	1.793e+000	1.800e+002	2.158e-001

Site : WCP SW Simulation : C

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	6.207e+001	9.709e+001	1.241e+002	8.429e+001
6.207e+000	9.992e+001	6.828e+001	9.639e+001	1.303e+002	8.221e+001
1.241e+001	9.981e+001	7.448e+001	9.559e+001	1.366e+002	7.997e+001
1.862e+001	9.967e+001	8.069e+001	9.466e+001	1.428e+002	7.759e+001
2.483e+001	9.948e+001	8.690e+001	9.361e+001	1.490e+002	7.506e+001
3.103e+001	9.925e+001	9.310e+001	9.243e+001	1.552e+002	7.241e+001
3.724e+001	9.896e+001	9.931e+001	9.110e+001	1.614e+002	6.964e+001
4.345e+001	9.861e+001	1.055e+002	8.963e+001	1.676e+002	6.676e+001
4.966e+001	9.819e+001	1.117e+002	8.801e+001	1.738e+002	6.380e+001
5.586e+001	9.768e+001	1.179e+002	8.623e+001	1.800e+002	6.076e+001

MYGRT Version 2.0

Simulation of BASE at WCP S

Horizontal, Areal Organic Solute

Background Concentration of BASE	:	Cbk =	0.000000	(ug/L)
Aquifer Concentration of BASE	:	Co =	100.000000	(ug/L)
Source Width:		W =	120.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	22.0	0	100.0	5.40	0.18000
A	6.6	220	22.0	0	100.0	3.40	0.45000
B	6.6	220	22.0	0	100.0	1.00	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.172e+002	9.976e-002	2.345e+002	0.000e+000
1.172e+001	5.357e+001	1.290e+002	4.094e-002	2.462e+002	0.000e+000
2.345e+001	2.864e+001	1.407e+002	1.580e-002	2.579e+002	0.000e+000
3.517e+001	1.523e+001	1.524e+002	5.713e-003	2.697e+002	0.000e+000
4.690e+001	8.035e+000	1.641e+002	1.928e-003	2.814e+002	0.000e+000
5.862e+001	4.179e+000	1.759e+002	6.059e-004	2.931e+002	0.000e+000
7.034e+001	2.128e+000	1.876e+002	1.769e-004	3.048e+002	0.000e+000
8.207e+001	1.054e+000	1.993e+002	4.791e-005	3.166e+002	0.000e+000
9.379e+001	5.029e-001	2.110e+002	1.202e-005	3.283e+002	0.000e+000
1.055e+002	2.297e-001	2.228e+002	2.789e-006	3.400e+002	0.000e+000

Site : WCP S   Simulation : A

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.172e+002	2.774e-002	2.345e+002	3.367e-006
1.172e+001	4.415e+001	1.290e+002	1.210e-002	2.462e+002	1.175e-006
2.345e+001	1.949e+001	1.407e+002	5.243e-003	2.579e+002	0.000e+000
3.517e+001	8.606e+000	1.524e+002	2.249e-003	2.697e+002	0.000e+000
4.690e+001	3.799e+000	1.641e+002	9.517e-004	2.814e+002	0.000e+000
5.862e+001	1.677e+000	1.759e+002	3.960e-004	2.931e+002	0.000e+000
7.034e+001	7.402e-001	1.876e+002	1.614e-004	3.048e+002	0.000e+000
8.207e+001	3.265e-001	1.993e+002	6.417e-005	3.166e+002	0.000e+000
9.379e+001	1.438e-001	2.110e+002	2.481e-005	3.283e+002	0.000e+000
1.055e+002	6.326e-002	2.228e+002	9.297e-006	3.400e+002	0.000e+000

Site : WCP S   Simulation : B

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.172e+002	6.880e+001	2.345e+002	1.858e+001
1.172e+001	9.889e+001	1.290e+002	6.346e+001	2.462e+002	1.525e+001
2.345e+001	9.739e+001	1.407e+002	5.794e+001	2.579e+002	1.235e+001
3.517e+001	9.546e+001	1.524e+002	5.235e+001	2.697e+002	9.865e+000
4.690e+001	9.307e+001	1.641e+002	4.678e+001	2.814e+002	7.776e+000
5.862e+001	9.019e+001	1.759e+002	4.134e+001	2.931e+002	6.046e+000
7.034e+001	8.681e+001	1.876e+002	3.610e+001	3.048e+002	4.637e+000
8.207e+001	8.294e+001	1.993e+002	3.116e+001	3.166e+002	3.507e+000
9.379e+001	7.862e+001	2.110e+002	2.656e+001	3.283e+002	2.615e+000
1.055e+002	7.388e+001	2.228e+002	2.236e+001	3.400e+002	1.923e+000

MYGRT Version 2.0

Simulation of SENS at WCP S

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/L)
Aquifer Concentration of SENS : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	22.0	0	100.0	1.40	0.18000
A	6.6	220	22.0	0	100.0	5.40	0.00000
B	6.6	220	22.0	0	100.0	1.20	0.45000
C	6.6	220	22.0	0	100.0	3.40	0.00000

Site : WCP S   Simulation : Base

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	7.229e+000	2.345e+002	3.164e-001
1.172e+001	7.723e+001	1.290e+002	5.482e+000	2.462e+002	2.174e-001
2.345e+001	5.963e+001	1.407e+002	4.135e+000	2.579e+002	1.473e-001
3.517e+001	4.602e+001	1.524e+002	3.099e+000	2.697e+002	9.823e-002
4.690e+001	3.550e+001	1.641e+002	2.306e+000	2.814e+002	6.448e-002
5.862e+001	2.736e+001	1.759e+002	1.701e+000	2.931e+002	4.163e-002
7.034e+001	2.106e+001	1.876e+002	1.243e+000	3.048e+002	2.643e-002
8.207e+001	1.619e+001	1.993e+002	8.989e-001	3.166e+002	1.648e-002
9.379e+001	1.241e+001	2.110e+002	6.427e-001	3.283e+002	1.010e-002
1.055e+002	9.489e+000	2.228e+002	4.539e-001	3.400e+002	6.077e-003

Site : WCP S Simulation : A

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	1.831e+000	2.345e+002	1.785e-005
1.172e+001	8.868e+001	1.290e+002	8.272e-001	2.462e+002	3.602e-006
2.345e+001	7.478e+001	1.407e+002	3.455e-001	2.579e+002	0.000e+000
3.517e+001	5.959e+001	1.524e+002	1.334e-001	2.697e+002	0.000e+000
4.690e+001	4.466e+001	1.641e+002	4.753e-002	2.814e+002	0.000e+000
5.862e+001	3.136e+001	1.759e+002	1.564e-002	2.931e+002	0.000e+000
7.034e+001	2.056e+001	1.876e+002	4.745e-003	3.048e+002	0.000e+000
8.207e+001	1.256e+001	1.993e+002	1.328e-003	3.166e+002	0.000e+000
9.379e+001	7.126e+000	2.110e+002	3.426e-004	3.283e+002	0.000e+000
1.055e+002	3.753e+000	2.228e+002	8.146e-005	3.400e+002	0.000e+000

Site : WCP S　　　　Simulation : B

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	1.342e+000	2.345e+002	1.736e-002
1.172e+001	6.498e+001	1.290e+002	8.713e-001	2.462e+002	1.113e-002
2.345e+001	4.223e+001	1.407e+002	5.658e-001	2.579e+002	7.117e-003
3.517e+001	2.744e+001	1.524e+002	3.672e-001	2.697e+002	4.530e-003
4.690e+001	1.783e+001	1.641e+002	2.383e-001	2.814e+002	2.870e-003
5.862e+001	1.159e+001	1.759e+002	1.545e-001	2.931e+002	1.808e-003
7.034e+001	7.530e+000	1.876e+002	1.001e-001	3.048e+002	1.131e-003
8.207e+001	4.893e+000	1.993e+002	6.475e-002	3.166e+002	7.029e-004
9.379e+001	3.179e+000	2.110e+002	4.183e-002	3.283e+002	4.333e-004
1.055e+002	2.065e+000	2.228e+002	2.698e-002	3.400e+002	2.648e-004

Site : WCP S Simulation : C

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	9.795e+000	2.345e+002	1.042e-002
1.172e+001	9.306e+001	1.290e+002	6.152e+000	2.462e+002	3.991e-003
2.345e+001	8.420e+001	1.407e+002	3.685e+000	2.579e+002	1.452e-003
3.517e+001	7.380e+001	1.524e+002	2.104e+000	2.697e+002	5.020e-004
4.690e+001	6.248e+001	1.641e+002	1.144e+000	2.814e+002	1.649e-004
5.862e+001	5.095e+001	1.759e+002	5.923e-001	2.931e+002	5.142e-005
7.034e+001	3.993e+001	1.876e+002	2.919e-001	3.048e+002	1.523e-005
8.207e+001	3.002e+001	1.993e+002	1.368e-001	3.166e+002	4.285e-006
9.379e+001	2.162e+001	2.110e+002	6.100e-002	3.283e+002	1.144e-006
1.055e+002	1.489e+001	2.228e+002	2.586e-002	3.400e+002	0.000e+000

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Simulation of BASE at WCP S

Horizontal, Areal Organic Solute

Background Concentration of BASE : Cbk = 0.000000 (ug/L)
Aquifer Concentration of BASE : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	22.0	0	100.0	5.40	0.18000
[illegible]	6.6	220	22.0	0	100.0	3.40	0.45000
B	6.6	220	22.0	0	100.0	1.00	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.236e+002	1.386e-001	2.370e+002	2.145e-004
1.030e+001	5.784e+001	1.339e+002	7.960e-002	2.473e+002	1.109e-004
2.061e+001	3.345e+001	1.442e+002	4.559e-002	2.576e+002	5.629e-005
3.091e+001	1.935e+001	1.545e+002	2.601e-002	2.679e+002	2.804e-005
4.121e+001	1.119e+001	1.648e+002	1.476e-002	2.782e+002	1.369e-005
5.152e+001	6.472e+000	1.752e+002	8.320e-003	2.885e+002	6.543e-006
6.182e+001	3.742e+000	1.855e+002	4.654e-003	2.988e+002	3.060e-006
7.212e+001	2.164e+000	1.958e+002	2.578e-003	3.091e+002	1.399e-006
8.242e+001	1.251e+000	2.061e+002	1.413e-003	3.194e+002	0.000e+000
9.273e+001	7.226e-001	2.164e+002	7.648e-004	3.297e+002	0.000e+000
1.030e+002	4.172e-001	2.267e+002	4.082e-004	3.400e+002	0.000e+00
1.133e+002	2.406e-001				

Site : WCP S Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.236e+002	1.802e-002	2.370e+002	6.655e-006
1.030e+001	4.875e+001	1.339e+002	8.785e-003	2.473e+002	3.243e-006
2.061e+001	2.377e+001	1.442e+002	4.283e-003	2.576e+002	1.580e-006
3.091e+001	1.159e+001	1.545e+002	2.088e-003	2.679e+002	0.000e+000
4.121e+001	5.648e+000	1.648e+002	1.018e-003	2.782e+002	0.000e+000
5.152e+001	2.754e+000	1.752e+002	4.961e-004	2.885e+002	0.000e+000
6.182e+001	1.342e+000	1.855e+002	2.419e-004	2.988e+002	0.000e+000
7.212e+001	6.544e-001	1.958e+002	1.179e-004	3.091e+002	0.000e+000
8.242e+001	3.190e-001	2.061e+002	5.747e-005	3.194e+002	0.000e+000
9.273e+001	1.555e-001	2.164e+002	2.801e-005	3.297e+002	0.000e+000
1.030e+002	7.582e-002	2.267e+002	1.365e-005	3.400e+002	0.000e+000
1.133e+002	3.696e-002				

Site : WCP S   Simulation : B

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.236e+002	9.151e+001	2.370e+002	6.918e+001
1.030e+001	9.979e+001	1.339e+002	9.008e+001	2.473e+002	6.651e+001
2.061e+001	9.950e+001	1.442e+002	8.853e+001	2.576e+002	6.376e+001
3.091e+001	9.915e+001	1.545e+002	8.686e+001	2.679e+002	6.095e+001
4.121e+001	9.871e+001	1.648e+002	8.506e+001	2.782e+002	5.809e+001
5.152e+001	9.818e+001	1.752e+002	8.313e+001	2.885e+002	5.519e+001
6.182e+001	9.756e+001	1.855e+002	8.109e+001	2.988e+002	5.227e+001
7.212e+001	9.683e+001	1.958e+002	7.893e+001	3.091e+002	4.934e+001
8.242e+001	9.600e+001	2.061e+002	7.665e+001	3.194e+002	4.642e+001
9.273e+001	9.505e+001	2.164e+002	7.426e+001	3.297e+002	4.351e+001
1.030e+002	9.399e+001	2.267e+002	7.177e+001	3.400e+002	4.064e+0[illegible]
1.133e+002	9.281e+001				

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Simulation of SENS at WCP S

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/L)
Aquifer Concentration of SENS : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	22.0	0	100.0	1.40	0.18000
[illegible]	6.6	220	22.0	0	100.0	5.40	0.00000
B	6.6	220	22.0	0	100.0	1.20	0.45000
C	6.6	220	22.0	0	100.0	3.40	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.236e+002	6.548e+000	2.370e+002	5.281e-001
1.030e+001	7.970e+001	1.339e+002	5.214e+000	2.473e+002	4.194e-001
2.061e+001	6.352e+001	1.442e+002	4.151e+000	2.576e+002	3.328e-001
3.091e+001	5.063e+001	1.545e+002	3.304e+000	2.679e+002	2.640e-001
4.121e+001	4.035e+001	1.648e+002	2.630e+000	2.782e+002	2.093e-001
5.152e+001	3.215e+001	1.752e+002	2.092e+000	2.885e+002	1.659e-001
6.182e+001	2.562e+001	1.855e+002	1.664e+000	2.988e+002	1.313e-001
7.212e+001	2.042e+001	1.958e+002	1.324e+000	3.091e+002	1.039e-001
8.242e+001	1.627e+001	2.061e+002	1.053e+000	3.194e+002	8.209e-002
9.273e+001	1.296e+001	2.164e+002	8.366e-001	3.297e+002	6.480e-002
1.030e+002	1.032e+001	2.267e+002	6.648e-001	3.400e+002	5.109e-0[illegible]
1.133e+002	8.222e+000				

Site : WCP S   Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.236e+002	1.932e+001	2.370e+002	2.195e-001
1.030e+001	9.610e+001	1.339e+002	1.463e+001	2.473e+002	1.245e-001
2.061e+001	9.115e+001	1.442e+002	1.081e+001	2.576e+002	6.872e-002
3.091e+001	8.517e+001	1.545e+002	7.785e+000	2.679e+002	3.690e-002
4.121e+001	7.829e+001	1.648e+002	5.466e+000	2.782e+002	1.927e-002
5.152e+001	7.071e+001	1.752e+002	3.739e+000	2.885e+002	9.791e-003
6.182e+001	6.266e+001	1.855e+002	2.492e+000	2.988e+002	4.838e-003
7.212e+001	5.443e+001	1.958e+002	1.617e+000	3.091e+002	2.325e-003
8.242e+001	4.629e+001	2.061e+002	1.022e+000	3.194e+002	1.087e-003
9.273e+001	3.852e+001	2.164e+002	6.289e-001	3.297e+002	4.938e-004
1.030e+002	3.134e+001	2.267e+002	3.767e-001	3.400e+002	2.182e-004
1.133e+002	2.490e+001				

Site : WCP S   Simulation : B

Concentration vs Distance at T =   45.00 (yr) and Y =   0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.236e+002	1.061e+000	2.370e+002	1.634e-002
1.030e+001	6.847e+001	1.339e+002	7.262e-001	2.473e+002	1.118e-002
2.061e+001	4.688e+001	1.442e+002	4.971e-001	2.576e+002	7.645e-003
3.091e+001	3.210e+001	1.545e+002	3.402e-001	2.679e+002	5.228e-003
4.121e+001	2.198e+001	1.648e+002	2.329e-001	2.782e+002	3.575e-003
5.152e+001	1.505e+001	1.752e+002	1.594e-001	2.885e+002	2.444e-003
6.182e+001	1.030e+001	1.855e+002	1.091e-001	2.988e+002	1.671e-003
7.212e+001	7.054e+000	1.958e+002	7.462e-002	3.091e+002	1.142e-003
8.242e+001	4.830e+000	2.061e+002	5.105e-002	3.194e+002	7.809e-004
9.273e+001	3.306e+000	2.164e+002	3.493e-002	3.297e+002	5.338e-004
1.030e+002	2.264e+000	2.267e+002	2.389e-002	3.400e+002	3.648e-00[illegible]
1.133e+002	1.550e+000				

Site : WCP S   Simulation : C

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.236e+002	4.319e+001	2.370e+002	3.775e+000
1.030e+001	9.802e+001	1.339e+002	3.730e+001	2.473e+002	2.751e+000
2.061e+001	9.546e+001	1.442e+002	3.177e+001	2.576e+002	1.971e+000
3.091e+001	9.230e+001	1.545e+002	2.667e+001	2.679e+002	1.389e+000
4.121e+001	8.851e+001	1.648e+002	2.205e+001	2.782e+002	9.628e-001
5.152e+001	8.412e+001	1.752e+002	1.797e+001	2.885e+002	6.561e-001
6.182e+001	7.917e+001	1.855e+002	1.441e+001	2.988e+002	4.396e-001
7.212e+001	7.373e+001	1.958e+002	1.138e+001	3.091e+002	2.895e-001
8.242e+001	6.790e+001	2.061e+002	8.849e+000	3.194e+002	1.875e-001
9.273e+001	6.181e+001	2.164e+002	6.771e+000	3.297e+002	1.193e-001
1.030e+002	5.556e+001	2.267e+002	5.097e+000	3.400e+002	7.463e-002
1.133e+002	4.931e+001				

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Simulation of BASE at WCP S

Horizontal, Areal Organic Solute

Background Concentration of BASE : Cbk = 0.000000 (ug/L)
Aquifer Concentration of BASE : Co = 100.000000 (ug/L)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	22.0	0	100.0	5.40	0.18000
A	6.6	220	22.0	0	100.0	3.40	0.45000
B	6.6	220	22.0	0	100.0	1.00	0.00000

Site : WCP S   Simulation : Base

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.172e+002	1.968e-001	2.345e+002	3.752e-004
1.172e+001	5.363e+001	1.290e+002	1.055e-001	2.462e+002	1.984e-004
2.345e+001	2.876e+001	1.407e+002	5.658e-002	2.579e+002	1.044e-004
3.517e+001	1.543e+001	1.524e+002	3.033e-002	2.697e+002	5.462e-005
4.690e+001	8.273e+000	1.641e+002	1.625e-002	2.814e+002	2.837e-005
5.862e+001	4.437e+000	1.759e+002	8.702e-003	2.931e+002	1.462e-005
7.034e+001	2.380e+000	1.876e+002	4.656e-003	3.048e+002	7.459e-006
8.207e+001	1.276e+000	1.993e+002	2.488e-003	3.166e+002	3.765e-006
9.379e+001	6.844e-001	2.110e+002	1.328e-003	3.283e+002	1.878e-006
1.055e+002	3.670e-001	2.228e+002	7.068e-004	3.400e+002	0.000e+000

Site : WCP S Simulation : A

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.172e+002	2.815e-002	2.345e+002	7.918e-006
1.172e+001	4.415e+001	1.290e+002	1.243e-002	2.462e+002	3.495e-006
2.345e+001	1.949e+001	1.407e+002	5.486e-003	2.579e+002	1.543e-006
3.517e+001	8.607e+000	1.524e+002	2.422e-003	2.697e+002	0.000e+000
4.690e+001	3.800e+000	1.641e+002	1.069e-003	2.814e+002	0.000e+000
5.862e+001	1.678e+000	1.759e+002	4.722e-004	2.931e+002	0.000e+000
7.034e+001	7.407e-001	1.876e+002	2.084e-004	3.048e+002	0.000e+000
8.207e+001	3.270e-001	1.993e+002	9.203e-005	3.166e+002	0.000e+000
9.379e+001	1.444e-001	2.110e+002	4.063e-005	3.283e+002	0.000e+000
1.055e+002	6.375e-002	2.228e+002	1.794e-005	3.400e+002	0.000e+000

Site : WCP S   Simulation : B

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	1.172e+002	9.504e+001	2.345e+002	8.262e+001
1.172e+001	9.983e+001	1.290e+002	9.412e+001	2.462e+002	8.098e+001
2.345e+001	9.959e+001	1.407e+002	9.313e+001	2.579e+002	7.926e+001
3.517e+001	9.929e+001	1.524e+002	9.206e+001	2.697e+002	7.747e+001
4.690e+001	9.892e+001	1.641e+002	9.093e+001	2.814e+002	7.561e+001
5.862e+001	9.847e+001	1.759e+002	8.972e+001	2.931e+002	7.366e+001
7.034e+001	9.794e+001	1.876e+002	8.844e+001	3.048e+002	7.165e+001
8.207e+001	9.733e+001	1.993e+002	8.710e+001	3.166e+002	6.956e+001
9.379e+001	9.664e+001	2.110e+002	8.568e+001	3.283e+002	6.740e+001
1.055e+002	9.588e+001	2.228e+002	8.418e+001	3.400e+002	6.517e+001

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Simulation of SENS at WCP S

Horizontal, Areal Organic Solute

Background Concentration of SENS :	Cbk =	0.000000	(ug/L)
Aquifer Concentration of SENS :	Co =	100.000000	(ug/L)
Source Width:	W =	120.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	22.0	0	100.0	1.40	0.18000
A	6.6	220	22.0	0	100.0	5.40	0.00000
B	6.6	220	22.0	0	100.0	1.20	0.45000
C	6.6	220	22.0	0	100.0	3.40	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	7.543e+000	2.345e+002	5.605e-001
1.172e+001	7.725e+001	1.290e+002	5.821e+000	2.462e+002	4.317e-001
2.345e+001	5.967e+001	1.407e+002	4.492e+000	2.579e+002	3.325e-001
3.517e+001	4.609e+001	1.524e+002	3.465e+000	2.697e+002	2.560e-001
4.690e+001	3.560e+001	1.641e+002	2.673e+000	2.814e+002	1.971e-001
5.862e+001	2.749e+001	1.759e+002	2.061e+000	2.931e+002	1.518e-001
7.034e+001	2.123e+001	1.876e+002	1.589e+000	3.048e+002	1.168e-001
8.207e+001	1.639e+001	1.993e+002	1.225e+000	3.166e+002	8.990e-002
9.379e+001	1.266e+001	2.110e+002	9.440e-001	3.283e+002	6.918e-002
1.055e+002	9.772e+000	2.228e+002	7.275e-001	3.400e+002	5.323e-002

Site : WCP S   Simulation : A

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	4.166e+001	2.345e+002	2.555e+000
1.172e+001	9.733e+001	1.290e+002	3.474e+001	2.462e+002	1.705e+000
2.345e+001	9.380e+001	1.407e+002	2.838e+001	2.579e+002	1.111e+000
3.517e+001	8.937e+001	1.524e+002	2.271e+001	2.697e+002	7.064e-001
4.690e+001	8.407e+001	1.641e+002	1.778e+001	2.814e+002	4.386e-001
5.862e+001	7.797e+001	1.759e+002	1.362e+001	2.931e+002	2.658e-001
7.034e+001	7.122e+001	1.876e+002	1.020e+001	3.048e+002	1.572e-001
8.207e+001	6.399e+001	1.993e+002	7.471e+000	3.166e+002	9.070e-002
9.379e+001	5.650e+001	2.110e+002	5.348e+000	3.283e+002	5.107e-002
1.055e+002	4.898e+001	2.228e+002	3.740e+000	3.400e+002	2.805e-002

Site : WCP S   Simulation : B

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	1.342e+000	2.345e+002	1.791e-002
1.172e+001	6.498e+001	1.290e+002	8.720e-001	2.462e+002	1.163e-002
2.345e+001	4.223e+001	1.407e+002	5.665e-001	2.579e+002	7.546e-003
3.517e+001	2.744e+001	1.524e+002	3.680e-001	2.697e+002	4.897e-003
4.690e+001	1.783e+001	1.641e+002	2.390e-001	2.814e+002	3.177e-003
5.862e+001	1.159e+001	1.759e+002	1.552e-001	2.931e+002	2.061e-003
7.034e+001	7.530e+000	1.876e+002	1.008e-001	3.048e+002	1.337e-003
8.207e+001	4.893e+000	1.993e+002	6.547e-002	3.166e+002	8.673e-004
9.379e+001	3.179e+000	2.110e+002	4.251e-002	3.283e+002	5.626e-004
1.055e+002	2.066e+000	2.228e+002	2.760e-002	3.400e+002	3.648e-004

Site : WCP S Simulation : C

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	1.172e+002	6.664e+001	2.345e+002	1.630e+001
1.172e+001	9.879e+001	1.290e+002	6.106e+001	2.462e+002	1.318e+001
2.345e+001	9.716e+001	1.407e+002	5.534e+001	2.579e+002	1.052e+001
3.517e+001	9.507e+001	1.524e+002	4.960e+001	2.697e+002	8.274e+000
4.690e+001	9.248e+001	1.641e+002	4.394e+001	2.814e+002	6.416e+000
5.862e+001	8.937e+001	1.759e+002	3.846e+001	2.931e+002	4.904e+000
7.034e+001	8.574e+001	1.876e+002	3.324e+001	3.048e+002	3.694e+000
8.207e+001	8.160e+001	1.993e+002	2.837e+001	3.166e+002	2.742e+000
9.379e+001	7.699e+001	2.110e+002	2.390e+001	3.283e+002	2.006e+000
1.055e+002	7.198e+001	2.228e+002	1.987e+001	3.400e+002	1.445e+000

MYGRT Version 2.0

Simulation of BASE at WCP SE

Horizontal, Areal Organic Solute

Background Concentration of BASE :	Cbk =	0.000000	(ug/L)
Aquifer Concentration of BASE :	Co =	100.000000	(ug/L)
Source Width:	W =	110.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
[illegible]se	14.0	220	22.0	0	100.0	5.40	0.18000
[illegible]	14.0	220	22.0	0	100.0	3.40	0.45000
B	14.0	220	22.0	0	100.0	1.00	0.00000

Site : WCP SE Simulation : Base

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	1.119e+001	1.034e+002	9.518e-001
5.172e+000	8.051e+001	5.690e+001	8.925e+000	1.086e+002	7.171e-001
1.034e+001	6.482e+001	6.207e+001	7.098e+000	1.138e+002	5.354e-001
1.552e+001	5.217e+001	6.724e+001	5.626e+000	1.190e+002	3.958e-001
2.069e+001	4.197e+001	7.241e+001	4.441e+000	1.241e+002	2.896e-001
2.586e+001	3.376e+001	7.759e+001	3.489e+000	1.293e+002	2.096e-001
3.103e+001	2.713e+001	8.276e+001	2.727e+000	1.345e+002	1.501e-001
3.621e+001	2.179e+001	8.793e+001	2.118e+000	1.397e+002	1.062e-001
4.138e+001	1.748e+001	9.310e+001	1.635e+000	1.448e+002	7.420e-002
4.655e+001	1.400e+001	9.828e+001	1.252e+000	1.500e+002	5.122e-002

Site : WCP SE Simulation : A

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	5.125e+000	1.034e+002	2.617e-001
5.172e+000	7.430e+001	5.690e+001	3.807e+000	1.086e+002	1.942e-001
1.034e+001	5.520e+001	6.207e+001	2.829e+000	1.138e+002	1.440e-001
1.552e+001	4.101e+001	6.724e+001	2.101e+000	1.190e+002	1.068e-001
2.069e+001	3.047e+001	7.241e+001	1.561e+000	1.241e+002	7.910e-002
2.586e+001	2.264e+001	7.759e+001	1.160e+000	1.293e+002	5.855e-002
3.103e+001	1.682e+001	8.276e+001	8.613e-001	1.345e+002	4.330e-002
3.621e+001	1.250e+001	8.793e+001	6.397e-001	1.397e+002	3.199e-002
4.138e+001	9.284e+000	9.310e+001	4.750e-001	1.448e+002	2.359e-002
4.655e+001	6.898e+000	9.828e+001	3.526e-001	1.500e+002	1.738e-002

Site : WCP SE   Simulation : B

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.968e+001	1.034e+002	9.803e+001
5.172e+000	9.999e+001	5.690e+001	9.960e+001	1.086e+002	9.772e+001
1.034e+001	9.998e+001	6.207e+001	9.951e+001	1.138e+002	9.738e+001
1.552e+001	9.996e+001	6.724e+001	9.940e+001	1.190e+002	9.699e+001
2.069e+001	9.994e+001	7.241e+001	9.927e+001	1.241e+002	9.656e+001
2.586e+001	9.992e+001	7.759e+001	9.913e+001	1.293e+002	9.609e+001
3.103e+001	9.989e+001	8.276e+001	9.896e+001	1.345e+002	9.557e+001
3.621e+001	9.985e+001	8.793e+001	9.877e+001	1.397e+002	9.500e+001
4.138e+001	9.980e+001	9.310e+001	9.855e+001	1.448e+002	9.437e+001
4.655e+001	9.975e+001	9.828e+001	9.831e+001	1.500e+002	9.369e+001

MYGRT Version 2.0

Simulation of SENS at WCP SE

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/L)
Aquifer Concentration of SENS : Co = 100.000000 (ug/L)
Source Width: W = 110.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	14.0	220	22.0	0	100.0	1.40	0.18000
A	14.0	220	22.0	0	100.0	5.40	0.00000
B	14.0	220	22.0	0	100.0	1.20	0.45000
C	14.0	220	22.0	0	100.0	3.40	0.00000

Site : WCP SE   Simulation : Base

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	4.689e+001	1.034e+002	2.189e+001
5.172e+000	9.271e+001	5.690e+001	4.346e+001	1.086e+002	2.027e+001
1.034e+001	8.595e+001	6.207e+001	4.028e+001	1.138e+002	1.876e+001
1.552e+001	7.968e+001	6.724e+001	3.734e+001	1.190e+002	1.737e+001
2.069e+001	7.387e+001	7.241e+001	3.461e+001	1.241e+002	1.607e+001
2.586e+001	6.848e+001	7.759e+001	3.207e+001	1.293e+002	1.487e+001
3.103e+001	6.349e+001	8.276e+001	2.972e+001	1.345e+002	1.375e+001
3.621e+001	5.886e+001	8.793e+001	2.754e+001	1.397e+002	1.271e+001
4.138e+001	5.456e+001	9.310e+001	2.551e+001	1.448e+002	1.174e+001
4.655e+001	5.058e+001	9.828e+001	2.363e+001	1.500e+002	1.084e+001

Site : WCP SE   Simulation : A

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	6.397e+001	1.034e+002	1.438e+001
5.172e+000	9.859e+001	5.690e+001	5.822e+001	1.086e+002	1.151e+001
1.034e+001	9.672e+001	6.207e+001	5.240e+001	1.138e+002	9.090e+000
1.552e+001	9.437e+001	6.724e+001	4.661e+001	1.190e+002	7.073e+000
2.069e+001	9.149e+001	7.241e+001	4.097e+001	1.241e+002	5.424e+000
2.586e+001	8.807e+001	7.759e+001	3.556e+001	1.293e+002	4.100e+000
3.103e+001	8.413e+001	8.276e+001	3.047e+001	1.345e+002	3.053e+000
3.621e+001	7.968e+001	8.793e+001	2.577e+001	1.397e+002	2.240e+000
4.138e+001	7.479e+001	9.310e+001	2.151e+001	1.448e+002	1.619e+000
4.655e+001	6.952e+001	9.828e+001	1.771e+001	1.500e+002	1.153e+000

Site : WCP SE   Simulation : B

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	2.466e+001	1.034e+002	6.081e+000
5.172e+000	8.694e+001	5.690e+001	2.144e+001	1.086e+002	5.286e+000
1.034e+001	7.558e+001	6.207e+001	1.864e+001	1.138e+002	4.595e+000
1.552e+001	6.571e+001	6.724e+001	1.621e+001	1.190e+002	3.995e+000
2.069e+001	5.713e+001	7.241e+001	1.409e+001	1.241e+002	3.472e+000
2.586e+001	4.966e+001	7.759e+001	1.225e+001	1.293e+002	3.018e+000
3.103e+001	4.318e+001	8.276e+001	1.065e+001	1.345e+002	2.624e+000
3.621e+001	3.754e+001	8.793e+001	9.256e+000	1.397e+002	2.281e+000
4.138e+001	3.263e+001	9.310e+001	8.047e+000	1.448e+002	1.982e+000
4.655e+001	2.837e+001	9.828e+001	6.995e+000	1.500e+002	1.723e+000

Site : WCP SE   Simulation : C

Concentration vs Distance at T = 20.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	8.393e+001	1.034e+002	4.331e+001
5.172e+000	9.947e+001	5.690e+001	8.073e+001	1.086e+002	3.902e+001
1.034e+001	9.876e+001	6.207e+001	7.725e+001	1.138e+002	3.489e+001
1.552e+001	9.785e+001	6.724e+001	7.350e+001	1.190e+002	3.094e+001
2.069e+001	9.671e+001	7.241e+001	6.952e+001	1.241e+002	2.722e+001
2.586e+001	9.532e+001	7.759e+001	6.535e+001	1.293e+002	2.375e+001
3.103e+001	9.365e+001	8.276e+001	6.103e+001	1.345e+002	2.054e+001
3.621e+001	9.169e+001	8.793e+001	5.662e+001	1.397e+002	1.762e+001
4.138e+001	8.941e+001	9.310e+001	5.216e+001	1.448e+002	1.499e+001
4.655e+001	8.683e+001	9.828e+001	4.771e+001	1.500e+002	1.263e+001

MYGRT Version 2.0

Simulation of BASE at WCP SE

Horizontal, Areal Organic Solute

Background Concentration of BASE : Cbk = 0.000000 (ug/L)
Aquifer Concentration of BASE : Co = 100.000000 (ug/L)
Source Width: W = 110.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	14.0	220	22.0	0	100.0	5.40	0.18000
A	14.0	220	22.0	0	100.0	3.40	0.45000
B	14.0	220	22.0	0	100.0	1.00	0.00000

Site : WCP SE   Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	1.146e+001	1.034e+002	1.312e+000
5.172e+000	8.053e+001	5.690e+001	9.231e+000	1.086e+002	1.056e+000
1.034e+001	6.484e+001	6.207e+001	7.433e+000	1.138e+002	8.499e-001
1.552e+001	5.222e+001	6.724e+001	5.985e+000	1.190e+002	6.838e-001
2.069e+001	4.205e+001	7.241e+001	4.819e+000	1.241e+002	5.500e-001
2.586e+001	3.386e+001	7.759e+001	3.881e+000	1.293e+002	4.423e-001
3.103e+001	2.727e+001	8.276e+001	3.124e+000	1.345e+002	3.555e-001
3.621e+001	2.196e+001	8.793e+001	2.516e+000	1.397e+002	2.857e-001
4.138e+001	1.768e+001	9.310e+001	2.025e+000	1.448e+002	2.294e-001
4.655e+001	1.424e+001	9.828e+001	1.630e+000	1.500e+002	1.841e-001

Site : WCP SE Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	5.125e+000	1.034e+002	2.627e-001
5.172e+000	7.430e+001	5.690e+001	3.808e+000	1.086e+002	1.952e-001
1.034e+001	5.520e+001	6.207e+001	2.829e+000	1.138e+002	1.450e-001
1.552e+001	4.101e+001	6.724e+001	2.102e+000	1.190e+002	1.077e-001
2.069e+001	3.047e+001	7.241e+001	1.562e+000	1.241e+002	8.003e-002
2.586e+001	2.264e+001	7.759e+001	1.160e+000	1.293e+002	5.946e-002
3.103e+001	1.682e+001	8.276e+001	8.620e-001	1.345e+002	4.418e-002
3.621e+001	1.250e+001	8.793e+001	6.405e-001	1.397e+002	3.282e-002
4.138e+001	9.285e+000	9.310e+001	4.758e-001	1.448e+002	2.439e-002
4.655e+001	6.898e+000	9.828e+001	3.535e-001	1.500e+002	1.812e-002

Site : WCP SE Simulation : B

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.986e+001	1.034e+002	9.932e+001
5.172e+000	1.000e+002	5.690e+001	9.983e+001	1.086e+002	9.924e+001
1.034e+001	9.999e+001	6.207e+001	9.980e+001	1.138e+002	9.914e+001
1.552e+001	9.998e+001	6.724e+001	9.976e+001	1.190e+002	9.904e+001
2.069e+001	9.997e+001	7.241e+001	9.971e+001	1.241e+002	9.894e+001
2.586e+001	9.996e+001	7.759e+001	9.966e+001	1.293e+002	9.883e+001
3.103e+001	9.995e+001	8.276e+001	9.961e+001	1.345e+002	9.871e+001
3.621e+001	9.993e+001	8.793e+001	9.954e+001	1.397e+002	9.858e+001
4.138e+001	9.991e+001	9.310e+001	9.948e+001	1.448e+002	9.845e+001
4.655e+001	9.989e+001	9.828e+001	9.940e+001	1.500e+002	9.831e+001

MYGRT Version 2.0

Simulation of SENS at WCP SE

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/L)
Aquifer Concentration of SENS : Co = 100.000000 (ug/L)
Source Width: W = 110.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	14.0	220	22.0	0	100.0	1.40	0.18000
A	14.0	220	22.0	0	100.0	5.40	0.00000
B	14.0	220	22.0	0	100.0	1.20	0.45000
C	14.0	220	22.0	0	100.0	3.40	0.00000

Site : WCP SE   Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	4.690e+001	1.034e+002	2.197e+001
5.172e+000	9.271e+001	5.690e+001	4.348e+001	1.086e+002	2.037e+001
1.034e+001	8.595e+001	6.207e+001	4.031e+001	1.138e+002	1.888e+001
1.552e+001	7.968e+001	6.724e+001	3.737e+001	1.190e+002	1.750e+001
2.069e+001	7.387e+001	7.241e+001	3.464e+001	1.241e+002	1.622e+001
2.586e+001	6.849e+001	7.759e+001	3.211e+001	1.293e+002	1.503e+001
3.103e+001	6.349e+001	8.276e+001	2.977e+001	1.345e+002	1.393e+001
3.621e+001	5.886e+001	8.793e+001	2.759e+001	1.397e+002	1.291e+001
4.138e+001	5.457e+001	9.310e+001	2.558e+001	1.448e+002	1.196e+001
4.655e+001	5.059e+001	9.828e+001	2.371e+001	1.500e+002	1.108e+001

Site : WCP SE Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.309e+001	1.034e+002	6.863e+001
5.172e+000	9.979e+001	5.690e+001	9.155e+001	1.086e+002	6.522e+001
1.034e+001	9.951e+001	6.207e+001	8.982e+001	1.138e+002	6.170e+001
1.552e+001	9.915e+001	6.724e+001	8.787e+001	1.190e+002	5.810e+001
2.069e+001	9.870e+001	7.241e+001	8.571e+001	1.241e+002	5.445e+001
2.586e+001	9.813e+001	7.759e+001	8.334e+001	1.293e+002	5.078e+001
3.103e+001	9.743e+001	8.276e+001	8.077e+001	1.345e+002	4.712e+001
3.621e+001	9.659e+001	8.793e+001	7.800e+001	1.397e+002	4.350e+001
4.138e+001	9.560e+001	9.310e+001	7.504e+001	1.448e+002	3.994e+001
4.655e+001	9.444e+001	9.828e+001	7.191e+001	1.500e+002	3.648e+001

Site : WCP SE   Simulation : B

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	2.466e+001	1.034e+002	6.081e+000
5.172e+000	8.694e+001	5.690e+001	2.144e+001	1.086e+002	5.287e+000
1.034e+001	7.558e+001	6.207e+001	1.864e+001	1.138e+002	4.596e+000
1.552e+001	6.571e+001	6.724e+001	1.621e+001	1.190e+002	3.995e+000
2.069e+001	5.713e+001	7.241e+001	1.409e+001	1.241e+002	3.473e+000
2.586e+001	4.966e+001	7.759e+001	1.225e+001	1.293e+002	3.019e+000
3.103e+001	4.318e+001	8.276e+001	1.065e+001	1.345e+002	2.624e+000
3.621e+001	3.754e+001	8.793e+001	9.257e+000	1.397e+002	2.281e+000
4.138e+001	3.263e+001	9.310e+001	8.047e+000	1.448e+002	1.983e+000
4.655e+001	2.837e+001	9.828e+001	6.996e+000	1.500e+002	1.723e+000

Site : WCP SE Simulation : C

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.847e+001	1.034e+002	9.112e+001
5.172e+000	9.996e+001	5.690e+001	9.810e+001	1.086e+002	8.983e+001
1.034e+001	9.990e+001	6.207e+001	9.766e+001	1.138e+002	8.842e+001
1.552e+001	9.983e+001	6.724e+001	9.716e+001	1.190e+002	8.689e+001
2.069e+001	9.973e+001	7.241e+001	9.658e+001	1.241e+002	8.523e+001
2.586e+001	9.961e+001	7.759e+001	9.591e+001	1.293e+002	8.345e+001
3.103e+001	9.946e+001	8.276e+001	9.516e+001	1.345e+002	8.154e+001
3.621e+001	9.928e+001	8.793e+001	9.431e+001	1.397e+002	7.951e+001
4.138e+001	9.906e+001	9.310e+001	9.335e+001	1.448e+002	7.737e+001
4.655e+001	9.879e+001	9.828e+001	9.229e+001	1.500e+002	7.511e+001

MYGRT Version 2.0

Simulation of BASE at WCP SE

Horizontal, Areal Organic Solute

Background Concentration of BASE :	Cbk =	0.000000	(ug/L)
Aquifer Concentration of BASE :	Co =	100.000000	(ug/L)
Source Width:	W =	110.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
[illegible]ase	14.0	220	22.0	0	100.0	5.40	0.18000
[illegible]	14.0	220	22.0	0	100.0	3.40	0.45000
B	14.0	220	22.0	0	100.0	1.00	0.00000

Site : WCP SE   Simulation : Base

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	1.146e+001	1.034e+002	1.314e+000
5.172e+000	8.053e+001	5.690e+001	9.232e+000	1.086e+002	1.058e+000
1.034e+001	6.484e+001	6.207e+001	7.434e+000	1.138e+002	8.522e-001
1.552e+001	5.222e+001	6.724e+001	5.986e+000	1.190e+002	6.862e-001
2.069e+001	4.205e+001	7.241e+001	4.820e+000	1.241e+002	5.525e-001
2.586e+001	3.386e+001	7.759e+001	3.882e+000	1.293e+002	4.449e-001
3.103e+001	2.727e+001	8.276e+001	3.126e+000	1.345e+002	3.582e-001
3.621e+001	2.196e+001	8.793e+001	2.517e+000	1.397e+002	2.884e-001
4.138e+001	1.768e+001	9.310e+001	2.027e+000	1.448e+002	2.323e-001
4.655e+001	1.424e+001	9.828e+001	1.632e+000	1.500e+002	1.870e-001

Site : WCP SE Simulation : A

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	5.125e+000	1.034e+002	2.627e-001
5.172e+000	7.430e+001	5.690e+001	3.808e+000	1.086e+002	1.952e-001
1.034e+001	5.520e+001	6.207e+001	2.829e+000	1.138e+002	1.450e-001
1.552e+001	4.101e+001	6.724e+001	2.102e+000	1.190e+002	1.077e-001
2.069e+001	3.047e+001	7.241e+001	1.562e+000	1.241e+002	8.003e-002
2.586e+001	2.264e+001	7.759e+001	1.160e+000	1.293e+002	5.946e-002
3.103e+001	1.682e+001	8.276e+001	8.620e-001	1.345e+002	4.418e-002
3.621e+001	1.250e+001	8.793e+001	6.405e-001	1.397e+002	3.282e-002
4.138e+001	9.285e+000	9.310e+001	4.758e-001	1.448e+002	2.439e-002
4.655e+001	6.898e+000	9.828e+001	3.535e-001	1.500e+002	1.812e-002

Site : WCP SE   Simulation : B

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	BASE (ug/L)	X (m)	BASE (ug/L)	X (m)	BASE (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.986e+001	1.034e+002	9.932e+001
5.172e+000	1.000e+002	5.690e+001	9.983e+001	1.086e+002	9.924e+001
1.034e+001	9.999e+001	6.207e+001	9.980e+001	1.138e+002	9.915e+001
1.552e+001	9.998e+001	6.724e+001	9.976e+001	1.190e+002	9.905e+001
2.069e+001	9.997e+001	7.241e+001	9.971e+001	1.241e+002	9.894e+001
2.586e+001	9.996e+001	7.759e+001	9.966e+001	1.293e+002	9.883e+001
3.103e+001	9.995e+001	8.276e+001	9.961e+001	1.345e+002	9.871e+001
3.621e+001	9.993e+001	8.793e+001	9.954e+001	1.397e+002	9.859e+001
4.138e+001	9.991e+001	9.310e+001	9.948e+001	1.448e+002	9.846e+001
4.655e+001	9.989e+001	9.828e+001	9.940e+001	1.500e+002	9.832e+001

MYGRT Version 2.0

Simulation of SENS at WCP SE

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/L)
Aquifer Concentration of SENS : Co = 100.000000 (ug/L)
Source Width: W = 110.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	14.0	220	22.0	0	100.0	1.40	0.18000
[illegible]	14.0	220	22.0	0	100.0	5.40	0.00000
B	14.0	220	22.0	0	100.0	1.20	0.45000
C	14.0	220	22.0	0	100.0	3.40	0.00000

Site : WCP SE   Simulation : Base

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	4.690e+001	1.034e+002	2.197e+001
5.172e+000	9.271e+001	5.690e+001	4.348e+001	1.086e+002	2.037e+001
1.034e+001	8.595e+001	6.207e+001	4.031e+001	1.138e+002	1.888e+001
1.552e+001	7.968e+001	6.724e+001	3.737e+001	1.190e+002	1.750e+001
2.069e+001	7.387e+001	7.241e+001	3.464e+001	1.241e+002	1.622e+001
2.586e+001	6.849e+001	7.759e+001	3.211e+001	1.293e+002	1.503e+001
3.103e+001	6.349e+001	8.276e+001	2.977e+001	1.345e+002	1.393e+001
3.621e+001	5.886e+001	8.793e+001	2.759e+001	1.397e+002	1.291e+001
4.138e+001	5.457e+001	9.310e+001	2.558e+001	1.448e+002	1.196e+001
4.655e+001	5.059e+001	9.828e+001	2.371e+001	1.500e+002	1.108e+001

Site : WCP SE Simulation : A

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.784e+001	1.034e+002	8.794e+001
5.172e+000	9.994e+001	5.690e+001	9.732e+001	1.086e+002	8.626e+001
1.034e+001	9.986e+001	6.207e+001	9.672e+001	1.138e+002	8.445e+001
1.552e+001	9.975e+001	6.724e+001	9.602e+001	1.190e+002	8.250e+001
2.069e+001	9.962e+001	7.241e+001	9.522e+001	1.241e+002	8.041e+001
2.586e+001	9.945e+001	7.759e+001	9.431e+001	1.293e+002	7.819e+001
3.103e+001	9.923e+001	8.276e+001	9.329e+001	1.345e+002	7.584e+001
3.621e+001	9.897e+001	8.793e+001	9.215e+001	1.397e+002	7.337e+001
4.138e+001	9.866e+001	9.310e+001	9.088e+001	1.448e+002	7.079e+001
4.655e+001	9.828e+001	9.828e+001	8.948e+001	1.500e+002	6.812e+001

Site : WCP SE   Simulation : B

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	2.466e+001	1.034e+002	6.081e+000
5.172e+000	8.694e+001	5.690e+001	2.144e+001	1.086e+002	5.287e+000
1.034e+001	7.558e+001	6.207e+001	1.864e+001	1.138e+002	4.596e+000
1.552e+001	6.571e+001	6.724e+001	1.621e+001	1.190e+002	3.995e+000
2.069e+001	5.713e+001	7.241e+001	1.409e+001	1.241e+002	3.473e+000
2.586e+001	4.966e+001	7.759e+001	1.225e+001	1.293e+002	3.019e+000
3.103e+001	4.318e+001	8.276e+001	1.065e+001	1.345e+002	2.624e+000
3.621e+001	3.754e+001	8.793e+001	9.257e+000	1.397e+002	2.281e+000
4.138e+001	3.263e+001	9.310e+001	8.047e+000	1.448e+002	1.983e+000
4.655e+001	2.837e+001	9.828e+001	6.996e+000	1.500e+002	1.723e+000

Site : WCP SE   Simulation : C

Concentration vs Distance at T = 65.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/L)	X (m)	SENS (ug/L)	X (m)	SENS (ug/L)
0.000e+000	1.000e+002	5.172e+001	9.963e+001	1.034e+002	9.768e+001
5.172e+000	9.999e+001	5.690e+001	9.953e+001	1.086e+002	9.732e+001
1.034e+001	9.998e+001	6.207e+001	9.942e+001	1.138e+002	9.691e+001
1.552e+001	9.996e+001	6.724e+001	9.930e+001	1.190e+002	9.645e+001
2.069e+001	9.994e+001	7.241e+001	9.915e+001	1.241e+002	9.595e+001
2.586e+001	9.991e+001	7.759e+001	9.898e+001	1.293e+002	9.539e+001
3.103e+001	9.987e+001	8.276e+001	9.878e+001	1.345e+002	9.478e+001
3.621e+001	9.982e+001	8.793e+001	9.856e+001	1.397e+002	9.410e+001
4.138e+001	9.977e+001	9.310e+001	9.830e+001	1.448e+002	9.337e+001
4.655e+001	9.970e+001	9.828e+001	9.801e+001	1.500e+002	9.257e+001

MYGRT Version 2.0

Simulation of SENS at WCP S

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/l)
Aquifer Concentration of SENS : Co = 100.000000 (ug/l)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	22	2.2	0	100.0	5.40	0.18000
A	6.6	22	2.2	0	100.0	3.40	0.45000
B	6.6	22	2.2	0	100.0	1.00	0.00000
C	6.6	2200	220.0	0	100.0	5.40	0.18000
D	6.6	2200	220.0	0	100.0	3.40	0.45000
E	6.6	2200	220.0	0	100.0	1.00	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.179e-005	2.370e+002	0.000e+000
1.030e+001	3.279e+001	1.339e+002	1.227e-006	2.473e+002	0.000e+000
2.061e+001	1.075e+001	1.442e+002	0.000e+000	2.576e+002	0.000e+000
3.091e+001	3.524e+000	1.545e+002	0.000e+000	2.679e+002	0.000e+000
4.121e+001	1.154e+000	1.648e+002	0.000e+000	2.782e+002	0.000e+000
5.152e+001	3.760e-001	1.752e+002	0.000e+000	2.885e+002	0.000e+000
6.182e+001	1.203e-001	1.855e+002	0.000e+000	2.988e+002	0.000e+000
7.212e+001	3.680e-002	1.958e+002	0.000e+000	3.091e+002	0.000e+000
8.242e+001	1.034e-002	2.061e+002	0.000e+000	3.194e+002	0.000e+000
9.273e+001	2.544e-003	2.164e+002	0.000e+000	3.297e+002	0.000e+000
1.030e+002	5.261e-004	2.267e+002	0.000e+000	3.400e+002	0.000e+000
1.133e+002	8.841e-005				

Site : WCP S Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	0.000e+000	2.370e+002	0.000e+000
1.030e+001	2.059e+001	1.339e+002	0.000e+000	2.473e+002	0.000e+000
2.061e+001	4.239e+000	1.442e+002	0.000e+000	2.576e+002	0.000e+000
3.091e+001	8.729e-001	1.545e+002	0.000e+000	2.679e+002	0.000e+000
4.121e+001	1.797e-001	1.648e+002	0.000e+000	2.782e+002	0.000e+000
5.152e+001	3.700e-002	1.752e+002	0.000e+000	2.885e+002	0.000e+000
6.182e+001	7.619e-003	1.855e+002	0.000e+000	2.988e+002	0.000e+000
7.212e+001	1.569e-003	1.958e+002	0.000e+000	3.091e+002	0.000e+000
8.242e+001	3.230e-004	2.061e+002	0.000e+000	3.194e+002	0.000e+000
9.273e+001	6.649e-005	2.164e+002	0.000e+000	3.297e+002	0.000e+000
1.030e+002	1.368e-005	2.267e+002	0.000e+000	3.400e+002	0.000e+000
1.133e+002	2.810e-006				

Site : WCP S   Simulation : B

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.000e+002	2.370e+002	9.246e+001
1.030e+001	1.000e+002	1.339e+002	9.999e+001	2.473e+002	8.855e+001
2.061e+001	1.000e+002	1.442e+002	9.998e+001	2.576e+002	8.337e+001
3.091e+001	1.000e+002	1.545e+002	9.995e+001	2.679e+002	7.688e+001
4.121e+001	1.000e+002	1.648e+002	9.990e+001	2.782e+002	6.919e+001
5.152e+001	1.000e+002	1.752e+002	9.978e+001	2.885e+002	6.055e+001
6.182e+001	1.000e+002	1.855e+002	9.955e+001	2.988e+002	5.136e+001
7.212e+001	1.000e+002	1.958e+002	9.912e+001	3.091e+002	4.210e+001
8.242e+001	1.000e+002	2.061e+002	9.838e+001	3.194e+002	3.326e+001
9.273e+001	1.000e+002	2.164e+002	9.717e+001	3.297e+002	2.527e+001
1.030e+002	1.000e+002	2.267e+002	9.527e+001	3.400e+002	1.843e+001
1.133e+002	1.000e+002				

Site : WCP S   Simulation : C

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	8.699e+000	2.370e+002	8.947e-001
1.030e+001	8.170e+001	1.339e+002	7.082e+000	2.473e+002	7.268e-001
2.061e+001	6.674e+001	1.442e+002	5.765e+000	2.576e+002	5.903e-001
3.091e+001	5.451e+001	1.545e+002	4.691e+000	2.679e+002	4.794e-001
4.121e+001	4.451e+001	1.648e+002	3.816e+000	2.782e+002	3.893e-001
5.152e+001	3.634e+001	1.752e+002	3.104e+000	2.885e+002	3.161e-001
6.182e+001	2.965e+001	1.855e+002	2.524e+000	2.988e+002	2.566e-001
7.212e+001	2.419e+001	1.958e+002	2.052e+000	3.091e+002	2.083e-001
8.242e+001	1.973e+001	2.061e+002	1.668e+000	3.194e+002	1.691e-001
9.273e+001	1.608e+001	2.164e+002	1.355e+000	3.297e+002	1.372e-001
1.030e+002	1.311e+001	2.267e+002	1.101e+000	3.400e+002	1.114e-001
1.133e+002	1.068e+001				

Site : WCP S Simulation : D

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	4.541e+000	2.370e+002	2.596e-001
1.030e+001	7.735e+001	1.339e+002	3.505e+000	2.473e+002	2.000e-001
2.061e+001	5.983e+001	1.442e+002	2.704e+000	2.576e+002	1.540e-001
3.091e+001	4.627e+001	1.545e+002	2.086e+000	2.679e+002	1.186e-001
4.121e+001	3.578e+001	1.648e+002	1.609e+000	2.782e+002	9.129e-002
5.152e+001	2.766e+001	1.752e+002	1.240e+000	2.885e+002	7.028e-002
6.182e+001	2.138e+001	1.855e+002	9.562e-001	2.988e+002	5.410e-002
7.212e+001	1.652e+001	1.958e+002	7.370e-001	3.091e+002	4.164e-002
8.242e+001	1.277e+001	2.061e+002	5.679e-001	3.194e+002	3.205e-002
9.273e+001	9.864e+000	2.164e+002	4.376e-001	3.297e+002	2.467e-002
1.030e+002	7.618e+000	2.267e+002	3.371e-001	3.400e+002	1.899e-002
1.133e+002	5.883e+000				

Site : WCP S Simulation : E

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	6.955e+001	2.370e+002	4.888e+001
1.030e+001	9.748e+001	1.339e+002	6.731e+001	2.473e+002	4.739e+001
2.061e+001	9.490e+001	1.442e+002	6.515e+001	2.576e+002	4.595e+001
3.091e+001	9.229e+001	1.545e+002	6.305e+001	2.679e+002	4.457e+001
4.121e+001	8.965e+001	1.648e+002	6.104e+001	2.782e+002	4.323e+001
5.152e+001	8.700e+001	1.752e+002	5.910e+001	2.885e+002	4.194e+001
6.182e+001	8.438e+001	1.855e+002	5.723e+001	2.988e+002	4.069e+001
7.212e+001	8.177e+001	1.958e+002	5.543e+001	3.091e+002	3.948e+001
8.242e+001	7.921e+001	2.061e+002	5.370e+001	3.194e+002	3.831e+001
9.273e+001	7.670e+001	2.164e+002	5.203e+001	3.297e+002	3.718e+001
1.030e+002	7.425e+001	2.267e+002	5.043e+001	3.400e+002	3.608e+001
1.133e+002	7.187e+001				

MYGRT Version 2.0

Simulation of SENS at WCP S

Horizontal, Areal Organic Solute

Background Concentration of SENS : Cbk = 0.000000 (ug/l)
Aquifer Concentration of SENS : Co = 100.000000 (ug/l)
Source Width: W = 120.000000 (m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	6.6	220	8.8	0	100.0	5.40	0.18000
	6.6	220	8.8	0	100.0	3.40	0.45000
B	6.6	220	8.8	0	100.0	1.00	0.00000
C	6.6	220	66.0	0	100.0	5.40	0.18000
D	6.6	220	66.0	0	100.0	3.40	0.45000
E	6.6	220	66.0	0	100.0	1.00	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.386e-001	2.370e+002	2.14[illegible]e-004
1.030e+001	5.784e+001	1.339e+002	7.961e-002	2.473e+002	1.110e-004
2.061e+001	3.345e+001	1.442e+002	4.560e-002	2.576e+002	5.634e-005
3.091e+001	1.935e+001	1.545e+002	2.601e-002	2.679e+002	2.806e-005
4.121e+001	1.119e+001	1.648e+002	1.476e-002	2.782e+002	1.370e-005
5.152e+001	6.472e+000	1.752e+002	8.323e-003	2.885e+002	6.549e-006
6.182e+001	3.742e+000	1.855e+002	4.655e-003	2.988e+002	3.063e-006
7.212e+001	2.164e+000	1.958e+002	2.579e-003	3.091e+002	1.401e-006
8.242e+001	1.251e+000	2.061e+002	1.414e-003	3.194e+002	0.000e+000
9.273e+001	7.227e-001	2.164e+002	7.651e-004	3.297e+002	0.000e+000
1.030e+002	4.172e-001	2.267e+002	4.084e-004	3.400e+002	0.000e+000
1.133e+002	2.406e-001				

Site : WCP S   Simulation : A

Concentration vs Distance at T =   45.00 (yr) and Y =   0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.802e-002	2.370e+002	6.659e-006
1.030e+001	4.875e+001	1.339e+002	8.785e-003	2.473e+002	3.246e-006
2.061e+001	2.377e+001	1.442e+002	4.283e-003	2.576e+002	1.582e-006
3.091e+001	1.159e+001	1.545e+002	2.088e-003	2.679e+002	0.000e+000
4.121e+001	5.648e+000	1.648e+002	1.018e-003	2.782e+002	0.000e+000
5.152e+001	2.754e+000	1.752e+002	4.962e-004	2.885e+002	0.000e+000
6.182e+001	1.342e+000	1.855e+002	2.419e-004	2.988e+002	0.000e+000
7.212e+001	6.544e-001	1.958e+002	1.179e-004	3.091e+002	0.000e+000
8.242e+001	3.190e-001	2.061e+002	5.749e-005	3.194e+002	0.000e+000
9.273e+001	1.555e-001	2.164e+002	2.802e-005	3.297e+002	0.000e+000
1.030e+002	7.582e-002	2.267e+002	1.366e-005	3.400e+002	0.000e+000
1.133e+002	3.696e-002				

Site : WCP S   Simulation : B

Concentration vs Distance at T =   45.00 (yr) and Y =   0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	9.454e+001	2.370e+002	7.487e+001
1.030e+001	9.989e+001	1.339e+002	9.347e+001	2.473e+002	7.224e+001
2.061e+001	9.974e+001	1.442e+002	9.226e+001	2.576e+002	6.950e+001
3.091e+001	9.954e+001	1.545e+002	9.091e+001	2.679e+002	6.667e+001
4.121e+001	9.930e+001	1.648e+002	8.942e+001	2.782e+002	6.374e+001
5.152e+001	9.900e+001	1.752e+002	8.778e+001	2.885e+002	6.075e+001
6.182e+001	9.863e+001	1.855e+002	8.600e+001	2.988e+002	5.771e+001
7.212e+001	9.819e+001	1.958e+002	8.406e+001	3.091e+002	5.462e+001
8.242e+001	9.766e+001	2.061e+002	8.197e+001	3.194e+002	5.153e+001
9.273e+001	9.704e+001	2.164e+002	7.974e+001	3.297e+002	4.843e+001
1.030e+002	9.632e+001	2.267e+002	7.737e+001	3.400e+002	4.534e+001
1.133e+002	9.549e+001				

Site : WCP S   Simulation : C

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.368e-001	2.370e+002	2.051e-004
1.030e+001	5.784e+001	1.339e+002	7.838e-002	2.473e+002	1.058e-004
2.061e+001	3.345e+001	1.442e+002	4.475e-002	2.576e+002	5.360e-005
3.091e+001	1.934e+001	1.545e+002	2.545e-002	2.679e+002	2.665e-005
4.121e+001	1.118e+001	1.648e+002	1.439e-002	2.782e+002	1.299e-005
5.152e+001	6.465e+000	1.752e+002	8.089e-003	2.885e+002	6.200e-006
6.182e+001	3.736e+000	1.855e+002	4.510e-003	2.988e+002	2.896e-006
7.212e+001	2.158e+000	1.958e+002	2.491e-003	3.091e+002	1.322e-006
8.242e+001	1.246e+000	2.061e+002	1.361e-003	3.194e+002	0.000e+000
9.273e+001	7.186e-001	2.164e+002	7.347e-004	3.297e+002	0.000e+000
1.030e+002	4.140e-001	2.267e+002	3.912e-004	3.400e+002	0.000e+000
1.133e+002	2.382e-001				

Site : WCP S   Simulation : D

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.791e-002	2.370e+002	6.395e-006
1.030e+001	4.875e+001	1.339e+002	8.714e-003	2.473e+002	3.104e-006
2.061e+001	2.377e+001	1.442e+002	4.239e-003	2.576e+002	1.506e-006
3.091e+001	1.159e+001	1.545e+002	2.061e-003	2.679e+002	0.000e+000
4.121e+001	5.648e+000	1.648e+002	1.002e-003	2.782e+002	0.000e+000
5.152e+001	2.753e+000	1.752e+002	4.872e-004	2.885e+002	0.000e+000
6.182e+001	1.342e+000	1.855e+002	2.367e-004	2.988e+002	0.000e+000
7.212e+001	6.538e-001	1.958e+002	1.150e-004	3.091e+002	0.000e+000
8.242e+001	3.185e-001	2.061e+002	5.587e-005	3.194e+002	0.000e+000
9.273e+001	1.552e-001	2.164e+002	2.713e-005	3.297e+002	0.000e+000
1.030e+002	7.557e-002	2.267e+002	1.317e-005	3.400e+002	0.000e+000
1.133e+002	3.679e-002				

Site : WCP S   Simulation : E

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	7.780e+001	2.370e+002	5.257e+001
1.030e+001	9.906e+001	1.339e+002	7.554e+001	2.473e+002	5.021e+001
2.061e+001	9.786e+001	1.442e+002	7.328e+001	2.576e+002	4.785e+001
3.091e+001	9.642e+001	1.545e+002	7.102e+001	2.679e+002	4.549e+001
4.121e+001	9.477e+001	1.648e+002	6.875e+001	2.782e+002	4.313e+001
5.152e+001	9.294e+001	1.752e+002	6.647e+001	2.885e+002	4.078e+001
6.182e+001	9.096e+001	1.855e+002	6.418e+001	2.988e+002	3.845e+001
7.212e+001	8.889e+001	1.958e+002	6.188e+001	3.091e+002	3.615e+001
8.242e+001	8.674e+001	2.061e+002	5.957e+001	3.194e+002	3.387e+001
9.273e+001	8.454e+001	2.164e+002	5.725e+001	3.297e+002	3.164e+001
1.030e+002	8.231e+001	2.267e+002	5.491e+001	3.400e+002	2.946e+001
1.133e+002	8.006e+001				

```
@echo off
rem This autoexec.bat is for machine 386AI
prompt $p$g
rem  3 1;33;44m    2J
PATH C:\DOS;c:\qemm;c:\;c:\util;c:\QPRO;c:\wp51;c:\abm72;
set fff=CDE -avpqc
set MachID=386AI
   util\keyboard
c:\qemm\loadhi /r:3 dosedit

C:\QEMM\LOADHI /R:1 C:\DOS\MODE COM2:9600,N,8,1,P
C:\DOS\MODE LPT1=COM2
CALL C:\BUFFALO\BUFF_SET.BAT
CALL WHATPRT.BAT
WAIT 2

rem     call shield.bat
logoff
```

MYGRT Version 2.0

Simulation of SENS at WCP S

Horizontal, Areal Organic Solute

Background Concentration of SENS	:	Cbk =	0.000000	(ug/l)
Aquifer Concentration of SENS	:	Co =	100.000000	(ug/l)
Source Width:		W =	120.000000	(m)

Run#	V	Dx	Dy	Ton	Toff	Rd	k
Base	1.0	33	3.3	0	100.0	5.40	0.18000
A	1.0	33	3.3	0	100.0	3.40	0.45000
B	1.0	33	3.3	0	100.0	1.00	0.00000
C	10.3	340	34.0	0	100.0	5.40	0.18000
D	10.3	340	34.0	0	100.0	3.40	0.45000
E	10.3	340	34.0	0	100.0	1.00	0.00000

Site : WCP S Simulation : Base

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	0.000e+000	2.370e+002	0.000e+000
1.030e+001	1.981e+001	1.339e+002	0.000e+000	2.473e+002	0.000e+000
2.061e+001	3.923e+000	1.442e+002	0.000e+000	2.576e+002	0.000e+000
3.091e+001	7.762e-001	1.545e+002	0.000e+000	2.679e+002	0.000e+000
4.121e+001	1.530e-001	1.648e+002	0.000e+000	2.782e+002	0.000e+000
5.152e+001	2.986e-002	1.752e+002	0.000e+000	2.885e+002	0.000e+000
6.182e+001	5.691e-003	1.855e+002	0.000e+000	2.988e+002	0.000e+000
7.212e+001	1.038e-003	1.958e+002	0.000e+000	3.091e+002	0.000e+000
8.242e+001	1.768e-004	2.061e+002	0.000e+000	3.194e+002	0.000e+000
9.273e+001	2.741e-005	2.164e+002	0.000e+000	3.297e+002	0.000e+000
1.030e+002	3.778e-006	2.267e+002	0.000e+000	3.400e+002	0.000e+000
1.133e+002	0.000e+000				

Site : WCP S   Simulation : A

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	0.000e+000	2.370e+002	0.000e+000
1.030e+001	1.265e+001	1.339e+002	0.000e+000	2.473e+002	0.000e+000
2.061e+001	1.599e+000	1.442e+002	0.000e+000	2.576e+002	0.000e+000
3.091e+001	2.022e-001	1.545e+002	0.000e+000	2.679e+002	0.000e+000
4.121e+001	2.557e-002	1.648e+002	0.000e+000	2.782e+002	0.000e+000
5.152e+001	3.234e-003	1.752e+002	0.000e+000	2.885e+002	0.000e+000
6.182e+001	4.089e-004	1.855e+002	0.000e+000	2.988e+002	0.000e+000
7.212e+001	5.171e-005	1.958e+002	0.000e+000	3.091e+002	0.000e+000
8.242e+001	6.539e-006	2.061e+002	0.000e+000	3.194e+002	0.000e+000
9.273e+001	0.000e+000	2.164e+002	0.000e+000	3.297e+002	0.000e+000
1.030e+002	0.000e+000	2.267e+002	0.000e+000	3.400e+002	0.000e+000
1.133e+002	0.000e+000				

Site : WCP S Simulation : B

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.163e+001	2.370e+002	3.642e-002
1.030e+001	9.498e+001	1.339e+002	8.102e+000	2.473e+002	1.764e-002
2.061e+001	8.862e+001	1.442e+002	5.469e+000	2.576e+002	8.258e-003
3.091e+001	8.108e+001	1.545e+002	3.576e+000	2.679e+002	3.735e-003
4.121e+001	7.258e+001	1.648e+002	2.263e+000	2.782e+002	1.632e-003
5.152e+001	6.348e+001	1.752e+002	1.387e+000	2.885e+002	6.892e-004
6.182e+001	5.415e+001	1.855e+002	8.219e-001	2.988e+002	2.811e-004
7.212e+001	4.500e+001	1.958e+002	4.713e-001	3.091e+002	1.108e-004
8.242e+001	3.639e+001	2.061e+002	2.614e-001	3.194e+002	4.215e-005
9.273e+001	2.860e+001	2.164e+002	1.402e-001	3.297e+002	1.549e-005
1.030e+002	2.184e+001	2.267e+002	7.267e-002	3.400e+002	5.499e-006
1.133e+002	1.618e+001				

Site : WCP S   Simulation : C

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	6.729e-001	2.370e+002	6.070e-003
1.030e+001	6.593e+001	1.339e+002	4.429e-001	2.473e+002	3.862e-003
2.061e+001	4.347e+001	1.442e+002	2.913e-001	2.576e+002	2.441e-003
3.091e+001	2.866e+001	1.545e+002	1.914e-001	2.679e+002	1.530e-003
4.121e+001	1.890e+001	1.648e+002	1.256e-001	2.782e+002	9.510e-004
5.152e+001	1.246e+001	1.752e+002	8.226e-002	2.885e+002	5.856e-004
6.182e+001	8.215e+000	1.855e+002	5.376e-002	2.988e+002	3.569e-004
7.212e+001	5.416e+000	1.958e+002	3.503e-002	3.091e+002	2.152e-004
8.242e+001	3.570e+000	2.061e+002	2.276e-002	3.194e+002	1.283e-004
9.273e+001	2.353e+000	2.164e+002	1.472e-002	3.297e+002	7.558e-005
1.030e+002	1.551e+000	2.267e+002	9.479e-003	3.400e+002	4.396e-005
1.133e+002	1.022e+000				

Site : WCP S   Simulation : D

Concentration vs Distance at T = 45.00 (yr) and Y = 0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	1.320e-001	2.370e+002	3.023e-004
1.030e+001	5.755e+001	1.339e+002	7.598e-002	2.473e+002	1.739e-004
2.061e+001	3.312e+001	1.442e+002	4.372e-002	2.576e+002	1.000e-004
3.091e+001	1.906e+001	1.545e+002	2.516e-002	2.679e+002	5.755e-005
4.121e+001	1.097e+001	1.648e+002	1.448e-002	2.782e+002	3.310e-005
5.152e+001	6.314e+000	1.752e+002	8.332e-003	2.885e+002	1.904e-005
6.182e+001	3.634e+000	1.855e+002	4.794e-003	2.988e+002	1.095e-005
7.212e+001	2.091e+000	1.958e+002	2.759e-003	3.091e+002	6.296e-006
8.242e+001	1.204e+000	2.061e+002	1.587e-003	3.194e+002	3.620e-006
9.273e+001	6.926e-001	2.164e+002	9.133e-004	3.297e+002	2.081e-006
1.030e+002	3.986e-001	2.267e+002	5.255e-004	3.400e+002	1.196e-006
1.133e+002	2.294e-001				

Site : WCP S   Simulation : E

Concentration vs Distance at T =   45.00 (yr) and Y =   0.00 (m)

X (m)	SENS (ug/l)	X (m)	SENS (ug/l)	X (m)	SENS (ug/l)
0.000e+000	1.000e+002	1.236e+002	9.492e+001	2.370e+002	8.394e+001
1.030e+001	9.986e+001	1.339e+002	9.415e+001	2.473e+002	8.267e+001
2.061e+001	9.968e+001	1.442e+002	9.333e+001	2.576e+002	8.136e+001
3.091e+001	9.944e+001	1.545e+002	9.247e+001	2.679e+002	7.999e+001
4.121e+001	9.916e+001	1.648e+002	9.156e+001	2.782e+002	7.858e+001
5.152e+001	9.883e+001	1.752e+002	9.060e+001	2.885e+002	7.711e+001
6.182e+001	9.844e+001	1.855e+002	8.960e+001	2.988e+002	7.560e+001
7.212e+001	9.799e+001	1.958e+002	8.856e+001	3.091e+002	7.403e+001
8.242e+001	9.748e+001	2.061e+002	8.747e+001	3.194e+002	7.242e+001
9.273e+001	9.692e+001	2.164e+002	8.634e+001	3.297e+002	7.075e+001
1.030e+002	9.631e+001	2.267e+002	8.516e+001	3.400e+002	6.903e+0[illegible]
1.133e+002	9.564e+001				

Appendix 8-C

Development of Waukegan Harbor Surface Water Model

APPENDIX 8-C
DEVELOPMENT OF WAUKEGAN HARBOR SURFACE WATER MODEL

INTRODUCTION

Lake Michigan has a strong influence on Waukegan Harbor, both in terms of hydrology and water quality. Without a river steadily flowing through the harbor, the transport of materials from the harbor to the lake is dependent on the degree of exchange of water between the lake and harbor. Measurement of the exchange between the harbor and the lake has been performed in a study performed by Argonne National Laboratory (ANL) in 1979 (Harrison, 1979). Findings from this study were used as the central element in the surface water models presented here.

Based on available information, a simple surface water model was constructed to estimate the annual flows into and from the harbor. The results of this model have been used to calculate the dilution factor for groundwater discharges from the WCP site resulting from mixing of Lake Michigan water in the Harbor. Based on a similar approach, the mixing of groundwater from the WCP site discharged directly to Lake Michigan through the Waukegan Beach area has also been estimated.

DEVELOPMENT OF SURFACE WATER QUALITY MODEL

The surface water model requires the consideration of several factors related to the conditions in the harbor, including geometry of the harbor, the nature of the contributing watershed, and the influence of Lake Michigan on the harbor and beach area through natural and other forces. The following sections discuss the factors included in the model development.

Waukegan Harbor Morphometry

Waukegan Harbor has a surface area of 43.2 acres and a mean depth of approximately 17.7 feet based on the U.S. Army Corps of Engineers Waukegan Harbor Plan, September 1984 (modified to portray the new slip at Larsen Marine and the filled Slip No. 3 on the north end of the harbor). The maximum depth of the harbor observed in 1993 sampling was approximately 18 feet. Waukegan Harbor has no natural inflows other than groundwater, direct precipitation, and very limited surface runoff from the land immediately adjacent to the harbor. There are storm sewer inflows to the harbor at Madison Street, at Clayton Street, at Slip No. 1, and private storm sewers serving waterfront properties such as National Gypsum, Larsen Marine, and OMC. All water leaving the harbor discharges to Lake Michigan through the outer harbor channel.

Waukegan Harbor Watershed

The watershed contributing to Waukegan Harbor is approximately 300 acres, with the main drainage area around the harbor. A storm sewer system provides drainage from part of the downtown area of Waukegan to the harbor. The land use of the watershed is primarily commercial/industrial, with significant areas of railroad and highway right-of-way and lesser areas of open and urban residential areas. The area adjacent to the harbor is relatively flat with unpaved surfaces, while the area near the city is highly impervious due to extensive development.

Waukegan Harbor

Waukegan Harbor is influenced by lake Michigan in several ways. Most significantly, there is an ongoing exchange of water with Lake Michigan.A detailed study of the hydrodynamics and water quality of Waukegan Harbor was conducted by ANL in 1979. Measurements were made of the flow characteristics in the harbor, and the interaction between the lake and the harbor. This study reported a measured average outflow from Waukegan Harbor to Lake Michigan of 2.8 cubic meters per second (cms). Based on this outflow rate, the hydraulic residence time of the harbor is calculated to be 3.9 days. The report also stated that outflows sufficient to flush the harbor in a period less than twenty four hours were observed on two occasions during 51 days of data collection. In addition to measuring flow rates from the harbor, a dye study was conducted which indicated that concentrations of an injected dye returned to background concentrations within eight days. Based on this information, the hydraulic residence time of Waukegan Harbor is believed to typically be within a range of one to eight days, with an open water season average of approximately four days.

The measurement of flows in the Waukegan Harbor channel by ANL provided evidence of a complex two layer flow pattern in the Harbor channel. The report showed that inflow and outflow occur simultaneously along the upper and lower portions of the Harbor channel, and the flows often appear to be in response to wind. The alternation of flow direction was observed at flow meters located throughout Waukegan Harbor. These reciprocal flows were not found to be dependent on changes in water level in the harbor. The report stated that the changes in water level in the harbor were related to the periodic changes in water level in the lake, but that changes in water level alone were not an effective mechanism for flushing the harbor.

Thus, when there is wind or during periods of unsettled weather, ongoing exchange of water between the lake and harbor is normal. During periods of low winds and calm weather, much less exchange may occur, and changes in the water quality of the harbor may be expected, including declining dissolved oxygen concentrations and rising concentrations of pollutants within the harbor.

The lake also influences the harbor by direct waves entering the harbor through the entrance channel, causing mixing throughout all or part of the harbor. In addition to the physical forces of nature acting on the harbor, the influence of the boat and ship traffic and the OMC engine testing operations in the harbor also cause additional mixing and movement of water in and out of the harbor.

Lake Michigan

Lake Michigan has a surface area of 22,400 square miles, with a mean depth of 276 feet and a volume of 1,170 cubic miles. The watershed contributing to Lake Michigan includes portions of Wisconsin, Illinois, and Michigan, covering 45,500 square miles, or twice the area of the lake surface. Lake Michigan has two outlets, a natural outlet through the Straits of Mackinac on the north end of the lake, and another through the Illinois Waterway near Chicago.

The water surface elevation of Lake Michigan varies daily and annually and is affected by hydrologic and other atmospheric conditions. In general, the annual water level varies seasonally, with the highest water levels occurring during July and the lowest water levels occurring during February.

The long-term average water surface elevation is 579.37 feet, the maximum recorded water level was 582.16 feet in 1986, and the minimum water level was 576.72 feet in 1964, based on mean sea level according to the National Geodetic Vertical Datum, 1929 adjustment. During 1993, the water level measured hourly at Milwaukee varied 0.86 foot during the year, with daily variations averaging 0.12 foot and with maximum and minimum daily fluctuations of 0.49 foot and 0.04 foot, respectively.

Factors influencing the water level of the lake include precipitation, evaporation, groundwater levels, natural changes in the outlet channels from the lake, surface water inflow from rain, and snowmelt from the surrounding watershed. Periodic fluctuations in the water level are strongly influenced by barometric pressure, winds, seiches, and, to a much lesser extent, lunar tides. These fluctuations tend to be highly variable, both temporally and spatially.

Seiches are hydrodynamic instabilities in lakes caused by atmospheric conditions. A seiche creates periodic oscillations in lake levels that are similar to tides, but are not influenced by the moon. Lunar tides exist in the Great Lakes, but the changes in lake levels due to tides are very small.

Two different types of seiches occur in Lake Michigan: surface seiches and internal seiches. Surface seiches are caused by strong winds pushing water to one side of the lake and the reaction of the water to the forces of gravity. The response of the lake to surface seiches are small compared to internal seiches. Internal seiches occur in stratified lakes in response to wind and atmospheric conditions. The denser hypolimnion is set in motion by steady winds and atmospheric pressure differences which cause the hypolimnion to oscillate in the direction of the wind for a period of time after the disturbance.

Winds are primarily responsible for the lake water currents in the Great Lakes (Lick, 1976). The lake currents are important in the transport of suspended and dissolved materials throughout the lake by convection, advection, and turbulent diffusion. The transfer of energy from wind to the lake is dependent on the strength of the wind, the length of the fetch, and the sheltering of the water surface from the wind by shoreline characteristics. The wind impacts the lake differently in deeper portions of the lake than near the shoreline. Waves created by winds react to the bottom as they approach the shoreline, causing a mixing of the shoreline waters as the waves approach.

Longshore currents are shoreline influences of waves meeting the shoreline of a lake or ocean at an oblique angle to the shoreline. These currents are important in the erosion of beach materials and in the transport of these materials throughout the lake. The velocity of longshore currents are dependent on incidence angle of the waves, the height of the wave, and the slope of the bottom of the lake in the breaker zone. The longshore currents in Lake Michigan in Kewaunee County, Wisconsin have been measured to range to 1.4 fps (0.435 m/s) (Lee, 1975).

The ANL study of Waukegan Harbor included measurement of currents at stations 0.6 miles (1 kilometer) and 2.8 miles (4.5 kilometers) from the shore. The direction of the currents was reported to be north on 39 days, south on 35 days, and near zero or switching on 20 days of the 94-day study period. The current speed ranged from too small to measure to 1.6 feet per second (0.5 meters per second). Current speeds were typically in the range of 0.03 to 0.3 feet per second

(0.01 to 0.1 meters per second), although speeds between 0.3 and 1 foot per second (0.1 and 0.3 meters per second) were not uncommon.

Based on theoretical equations for longshore current velocities and wave characteristics of Lake Michigan, longshore current velocities could exceed 2.5 feet per second (0.75 meters per second) along the westerly shore of Lake Michigan near Waukegan. As evidenced by the littoral transport of beach materials in the area, longshore currents in Lake Michigan near Waukegan generally flow from north to south.

Waukegan Manufactured Gas and Coke Plant Site

The WCP site impacts Waukegan Harbor and Lake Michigan primarily through groundwater discharges driven by surface water infiltration over the site. Surface water runoff resulting from rainfall and snowmelt event arguably could discharge from the WCP site. However, due to the lack of topographic relief and lack of impervious surface area on the site, surface water runoff is assumed to be minimal. Groundwater flows from the WCP site to both the harbor and the lake are small in terms of volume, but are potentially significant in terms of the impacts of the site on the water quality. The results of groundwater modeling for the WCP site provide an estimate of the groundwater flows from the site for the surface water model.

Conceptual Surface Water Model

The concept of the surface water model is shown on Figure 8-C-1. The purpose of this model is to determine the flushing, or dilution factor, of the Waukegan Harbor and the relative influence of the watershed, Lake Michigan, and the WCP site groundwater discharges. A simplified water budget for Waukegan Harbor is used for the Waukegan Harbor model and is given as:

$$\Delta S = Q_{SW} + Q_{WCP} +/- Q_{LAKE} +/- \text{Miscellaneous Sources} \qquad \text{Eqn. 8-C-1}$$

where:

ΔS = Change in water volume of the harbor

Q_{SW} = surface water inflows from the watershed

Q_{WCP} = groundwater inflows from the WCP site

Q_{LAKE} = Flow exchanges between the harbor and Lake Michigan

Miscellaneous Sources = Other flows to and from the harbor

The following methods were used to determine each parameters of the model:

- Change in Water Volume of the Harbor (ΔS). Water surface elevations measured during 1993 were used to calculate the change in storage between time steps. The difference in water surface level is multiplied by a constant water surface area to determine the volume of water added to, or removed from, the harbor on an hourly basis.

  $$\Delta S = (\Delta \text{Water Level} \times \text{Harbor Surface Area})$$

  This volume is either drawn from or discharged to Lake Michigan, according to the direction of water level change.

- Surface Water Inflows from the Watershed (Q_{SW}). Watershed surface water inflows to the harbor were calculated as the product of the reported annual watershed runoff yield in the Waukegan area times the watershed area. The watershed runoff are applied in the model as a constant rate of flow for the entire modeling period.

- Groundwater Inflows from the WCP Site (Q_{WCP}). Groundwater inflows from the WCP site to Waukegan Harbor and Lake Michigan were determined as a part of groundwater modeling conducted for the Remedial Investigations of the WCP site. Groundwater discharges are applied in the model as a constant rate of flow for the entire modeling period.

- Flow Exchanges between Waukegan Harbor and Lake Michigan (Q_{LAKE}). Water flows into and out of the harbor simultaneously. Wind-induced currents, and other influences such as density differences (i.e., due to water temperature) and wave motion create flow situations in which inflows to the harbor enter at the surface of the harbor channel, while a reverse flow to the lake exists at the bottom. At other times, these influences cause inflows at the bottom and outflows at the surface. These flows produce a flushing effect on the harbor, which controls the amount of water mixing with WCP site groundwater discharges. The model treats the exchange of water between Waukegan Harbor and Lake Michigan as a constant volumetric flow rate. The volumetric flow rates modeled reflect the flow rates indicated in the ANL study.

- Other Flows to and from the Harbor (Miscellaneous Sources). All minor inflows to and from the harbor are assumed to be negligible.

- Application of Model to Lake Michigan. An approach similar to the modeling of Waukegan Harbor was applied to Lake Michigan. The conceptual model for Lake Michigan is shown on Figure 8-C-2. The main difference between this model and the harbor model is that the control volume is not confined, and water flows into and out of the control volume from multiple directions. Discharges associated with changing lake levels were not included in this model, only the effect of lake and longshore currents were considered. The boundaries of the lake segment were defined as that part of the beach adjacent to the WCP site extending to a depth of 20 feet. This segment was expected to include practically all of the zone of groundwater discharge from the WCP site to Lake Michigan.

Modeling Assumptions

The assumptions made in the development of the surface water model include:

- The harbor is assumed to be well mixed. Stratification due to temperature or density differences are assumed to be negligible, and the impact of the lake and the WCP site are assumed to affect the entire harbor volume instantaneously.

- Groundwater from other areas surrounding the harbor have not been included in the model. This assumes that the volume of groundwater from these areas is small.

- It is assumed that groundwater and surface water inflows from the WCP site and the surrounding watershed can be applied as a constant discharge to the site, rather than a time-varying discharge which is dependent on season or atmospheric conditions.

- Water withdrawn from the harbor for cooling or industrial process purposes are offset by corresponding discharges to the harbor.

- Direct precipitation on the harbor water surface is equal to the direct evaporation during the modeling period. This is not true in reality, but the difference between direct precipitation and evaporation is small compared to other inflow sources.

- It has been assumed the flushing of the harbor by wind-induced reciprocal flows can be included as a constant rate of discharge. This discharge augments the lake inflow calculated by continuity to achieve the observed residence times of the Harbor.

<u>Model Elements</u>

Stormwater Inflows

Stormwater inflows to the harbor from the watershed are estimated to be approximately 350 acre-feet per year, based on 14 inches annual runoff (Hey and Associates, 1993) over the 300-acre watershed. The model uses a constant daily inflow from surface water of 1 acre-foot per day.

The average annual rainstorm is 0.27 inch over a duration of 5.7 hours and an average period between rainfall events of 72 hours (U.S. EPA, 1983). The 100-year 24-hour precipitation is 6.4 inches, and the 2-year 24-hour event is 2.8 inches (IEPA, 1993a).

Lake Michigan Inflows

The ANL study found reciprocal flows normally occur between Lake Michigan and Waukegan Harbor, without respect to water levels or seiche effects.

Consequently, the reciprocal flows have been included in the model as a constant rate of exchange between the harbor and the lake. The rate has been calculated as the volumetric flow necessary to achieve hydraulic residence times of 1 day, 3.9 days, and 8 days, as observed in the ANL study. In addition to the reciprocal flows, minor exchanges between the lake and harbor determined by changes in harbor water levels are included in the model.

Periodic fluctuations of water level in Lake Michigan is a part of the flushing mechanism for Waukegan Harbor. The water level of the harbor was measured on a continuous basis between October 28 and November 7, 1993 by Barr Engineering Co. Measured harbor water levels indicate daily fluctuations in the average water level of 0.5+ foot and nearly 1 foot between maximum and minimum daily levels. Over the two-week monitoring period, the water level in Waukegan Harbor fluctuated nearly 2 feet.

The monitoring data from Waukegan Harbor was compared with Lake Michigan water level measurements recorded during the same period at the U.S. Coast Guard station in the Milwaukee Harbor (Figure 8-C-3). This comparison indicated that instantaneous readings at Milwaukee are different than at Waukegan, but average water levels during daily and weekly periods are similar.

In Milwaukee Harbor, changes in lake level have been associated with complex flow conditions within the harbor (House, 1987). As the lake level increases, water flows into the harbor from the lake and to the lake as the water level recedes. The 1979 study of Waukegan Harbor conducted by ANL indicates that a similar condition exists in Waukegan Harbor. This effect has been included in the model using a simple mass balance calculation for the volume of water gained or lost by the harbor.

Groundwater Inflows

Groundwater from the WCP site flows both westerly to Waukegan Harbor and easterly to Lake Michigan. The annual inflow from WCP groundwater to the harbor is estimated to be 34.3 acre-feet (42,400 cubic meters), based on the groundwater model developed for the WCP site. Groundwater discharges directly to Lake Michigan through the Waukegan Beach area is estimated by the groundwater model to be 32.6 acre-feet (40,300 cubic meters) per year. Other groundwater inflows to the harbor are assumed to exist, but have not been included in this estimate.

Miscellaneous Sources

Water is withdrawn from Waukegan Harbor for use by OMC for noncontact cooling water. The NPDES permit for OMC lists eight permitted outfalls from the site that discharge stormwater and noncontact cooling water. Of these outfalls, three are associated with noncontact cooling water and the withdrawal of water from the harbor. Based on the NPDES permit for these outfalls, OMC may discharge up to 2.4 million gallons per day (2,680 acre-feet per year) to the harbor. The volume of water withdrawn from the harbor would be equal to the corresponding discharge.

<u>Model Calibration</u>

The surface water model is a simple mass balance model. Calibration in the sense of adjusting model factors to fit observed data was performed to obtain the specified hydraulic residence times selected for modeling. This type of calibration is the appropriate calibration for this model. Three cases using different rates of reciprocal flow were analyzed. The three cases were chosen to produce hydraulic residence times of 1 day, 3.9 days, and 8 days based on the ANL study. This approach provides a range of potential dilution factors for the harbor that may be compared with the dilution factor calculated from concentrations of a given parameter in WCP groundwater samples and in Waukegan Harbor surface water samples.

RESULTS

Model Runs

Waukegan Harbor

The results of the surface water model are shown in Table 8-C-1. Each of the modeled scenarios are discussed in the following sections.

- Case 1: 8 Day Hydraulic Residence Time

  Based on the model results for this case, the annual outflow from the harbor to the lake is 42.9×10^6 m^3/yr. This relates to a hydraulic residence time of 8 days for the harbor. The groundwater discharge from the WCP site accounts for less than 0.1 percent of the total discharge from the harbor to the lake. The dilution factor calculated from the outflow for Case 1 would be approximately 1,000.

- Case 2: 3.9 Day Hydraulic Residence Time

  Based on the model results, the annual outflow from the harbor to the lake is 88.2×10^6 m^3/yr. This relates to a hydraulic residence time of 3.9 days for the harbor. The groundwater discharge from the WCP site accounts for less than 0.05 percent of the total discharge from the harbor to the lake. The dilution factor calculated from the outflow for Case 2 would be approximately 2,100.

- Case 3: 1 Day Hydraulic Residence Time

  Based on the model results, the annual outflow from the harbor to the lake is 345.5×10^6 m^3/yr. This relates to a hydraulic residence time of one day for the harbor. The groundwater discharge from the WCP site accounts for less than 0.02 percent of the total discharge from the harbor to the lake. The dilution factor calculated from the outflow for Case 3 would be approximately 8,100.

Lake Michigan

The results of the surface water model are shown in Table 8-C-2. Each of the modeled scenarios are discussed in the following sections.

- Case 1: Assuming Zero Reciprocal Flow Exchange, Inflow from Lake Only Due to Lake Currents

Based on the model results, the annual flow through the beach area is estimated to be 445.0 x 10^6 m^3/yr. This would relate to a hydraulic residence time for the segment of one day. The average flow velocity through the segment of Lake Michigan included in this model was calculated to be 0.01 m/s. The range of lake current and longshore current velocities measured in the ANL study were found to range from 0 to 0.5 m/s and were commonly 0.1 m/s, ten times the modeled velocity. The groundwater discharge from the WCP site accounts for less than 0.01 percent of the total water flowing into the segment. The dilution factor calculated for the lake segment was 11,200.

Sensitivity Analysis

The sensitivity of the model to harbor flushing rates was computed as Case 1, Case 2 (representative), and Case 3, and is summarized in Table 8-C-1.

The sensitivity of the surface water model to groundwater mass loadings was evaluated for the sensitivity range computed in Appendix 8-A. The analysis used the representative flushing period (3.9 days) for the harbor in order to gage the effects of changing the groundwater inputs. The analysis is summarized in Table 8-C-3. The analysis was done for the maximum and minimum loadings for both Waukegan Harbor and Lake Michigan. The change in dilution factor is inversely proportional to the change in groundwater flow rate. The change in predicted phenol concentration in the surface water is directly proportional to groundwater flow rate and mass loading.

Annual Discharge from Waukegan Harbor to Lake Michigan

The total inflow of water to the harbor from all sources, other than from the lake, totals less than 0.01 percent of the total inflow to the lake. Due to the small size of the contributing watershed and surface area of the harbor, Waukegan Harbor has a very small influence on the total inflow of water to Lake Michigan. The harbor may have some local influence on the near-shore currents and local water and sediment quality.

Model Refinements

The model does not currently account for natural attenuation mechanisms such as biodegradation, volatilization, and sedimentation. In order to model the changing interactions between the harbor and lake over time, the model would need to link the reciprocal flows to a physical cause, such as wind speed and direction.

Model Limitations

This section of the report states the limitations of the surface water model developed for the evaluation of the WCP site on Waukegan Harbor and Lake Michigan.

- Thermal stratification is not considered in the model. The ANL data and field measurements during the RI investigation suggest this may not be an important limitation in modeling Waukegan Harbor.

- The hydrodynamics of the harbor channel have not been analyzed for this model. It has been assumed that the geometric configuration harbor does not restrict or enhance flows in or out of the harbor. The actual volume of water flowing to and from the harbor is actually dependent on a variety of factors, such as wind direction and speed, differences in water temperature between the lake and harbor, lake currents, as well as changes in lake levels due to seiches and other hydrodynamic instabilities within the lake.

- Discharge from the harbor is assumed to be replaced by pristine lake water in the reciprocal exchange process. The model does not allow materials discharged from the harbor to return into the harbor. The change in water surface level actually occurs on a relatively short time scale, on the order of several minutes, so, for the small portion of the exchange between lake and harbor that is dependent on water level changes, it may be reasonable to assume that harbor water will flow into and out of the harbor more than once during the one hour time step used in the model. The actual dilution of the harbor water over this time is difficult to estimate.

- The harbor sediments were not considered as a pollutant source in the model.

- Stormwater inflows from the watershed were applied as a constant inflow in the model. Stormwater runoff from the watershed will not discharge a significant flow for more than a day after a storm event. This simplification of the model provides slightly greater flushing during dry weather, and much lower flushing during periods of large storm events. The volume of surface water runoff from the watershed to the harbor is very small compared to the volume of water entering the harbor from the lake.

- The reciprocal flows used in the model are assumed to be constant throughout the year. The ANL study was completed during the spring and summer of 1979. The actual characteristics of the reciprocal flows during periods of ice cover is unknown.

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TABLE 8-C-1

SURFACE WATER MODEL RESULTS

WAUKEGAN MANUFACTURED GAS AND COKE PLANT SITE

WAUKEGAN HARBOR	CASE 1	CASE 2	CASE 3
Stormwater Inflows (m^3/yr)	432,000	432,000	432,000
WCP Site Groundwater (m^3/yr)	42,400	42,400	42,400
Lake Inflows to Harbor (m^3/yr)	20,830,000	20,830,000	20,830,000
Reciprocal Flows (m^3/yr)	22,090,000	67,320,000	324,660,000
Harbor Outflow (m^3/yr)	42,920,000 (1.4 m^3/s)	88,150,000 (2.8 m^3/s)	345,490,000 (11.0 m^3/s)
Dilution Factor[1] Based on Flow Volume	1,000	2,100	8,100
Hydraulic Residence Time (days)	8	3.9	1
Predicted Phenol Concentration without Degradation (mg/L)	0.020	0.013	0.008
Measured Phenol Concentration at Harbor Outlet (mg/L)	<0.006	<0.006	<0.006
Dilution Factor[2] Based on Concentration	2,400	2,400	2,400

[1]Dilution factor based on flow volume = outflow from harbor/WCP site groundwater discharge.

[2]Dilution factor based on concentrations = phenol concentrations of WCP site groundwater/ Waukegan Harbor outlet phenol concentration. Because the harbor outlet phenol concentration was reported as not detected (detection limit of 0.006 mg/L), the concentration was assumed to be 0.006 mg/L.

TABLE 8-C-2

SURFACE WATER MODEL RESULTS

WAUKEGAN MANUFACTURED GAS AND COKE PLANT SITE

WAUKEGAN HARBOR	CASE 1	COMMENTS
Stormwater Inflows (m^3/yr)	0	
WCP Site Groundwater (m^3/yr)	40,300	
Lake Inflows to Harbor (m^3/yr)	445,300,000	
Reciprocal Flows (m^3/yr)	0	
Lake Segment Outflow (m^3/yr)	445,440,300	
Dilution Factor[1] Based on Flow Volume	11,100	Based on the ANL report data, the actual average dilution factor is likely to be 10 or more times the computed dilution factor.
Hydraulic Residence Time (days)	1	
Predicted Phenol Concentration without Degradation (mg/L)	<0.006	
Measured Phenol Concentration at Harbor Outlet (mg/L)	<0.006	

[1]Dilution factor based on flow volume = outflow from harbor/WCP site groundwater discharge.

TABLE 8-C-3

SENSITIVITY RANGE FOR GROUNDWATER MASS LOADING RATES

RECEIVING WATER	CASE	GROUNDWATER DISCHARGE TO HARBOR $(ft^3/day)/(m^3/year)$	DILUTION FACTOR BASED ON FLOW VOLUME	GROUNDWATER MASS LOADING RATE - PHENOL (lbs/day)	PREDICTED CONCENTRATION WITHOUT DEGRADATION - PHENOL[1] (mg/L)
Waukegan Harbor	Representative	4,100/42,400	2,100	3.7	0.013
	Sensitivity to 80% Decrease in Groundwater Discharge	820/8,480	10,400	0.75	0.007
	Sensitivity to 50% Increase in Groundwater Discharge	6,200/63,600	1,400	5.7	0.017
Lake Michigan	Representative	3,900/40,300	11,100	0.002	<.006
	Sensitivity to 80% Decrease in Groundwater Discharge	780/8,060	55,000	0	<.006
	Sensitivity to Aquifer Total Organic Carbon (Appendix 8-A)	3,900/40,300	55,000	0.330	0.008
	Sensitivity to 50% Increase in Groundwater Discharge	5,850/60,450	7,300	0.046	0.006

[1] Lake Michigan phenol concentration assumed at detection limit 0.006 mg/L.

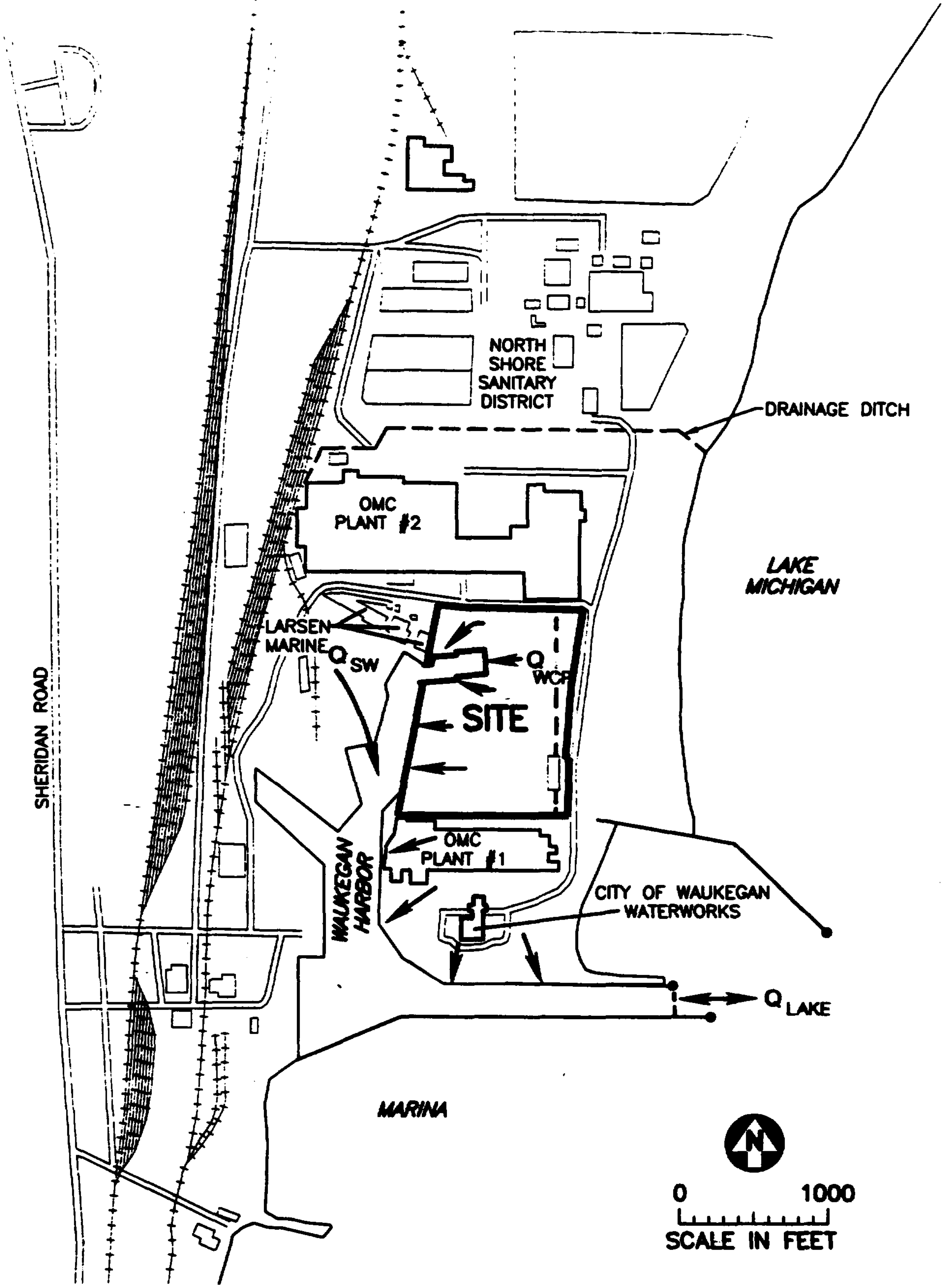

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Figure 8-C-1

WAUKEGAN HARBOR CONCEPTUAL SURFACE WATER MODEL

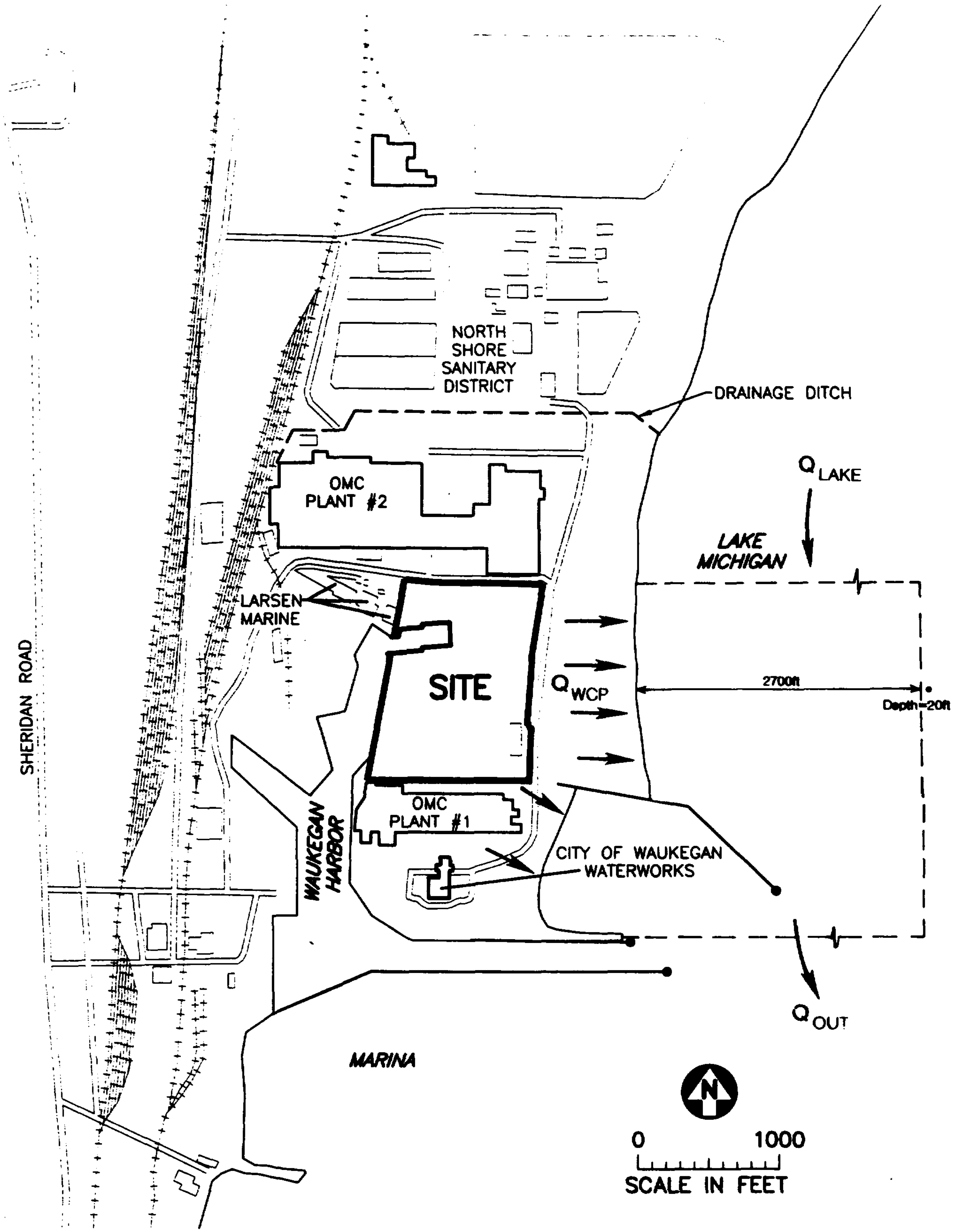


Figure 8-C-2

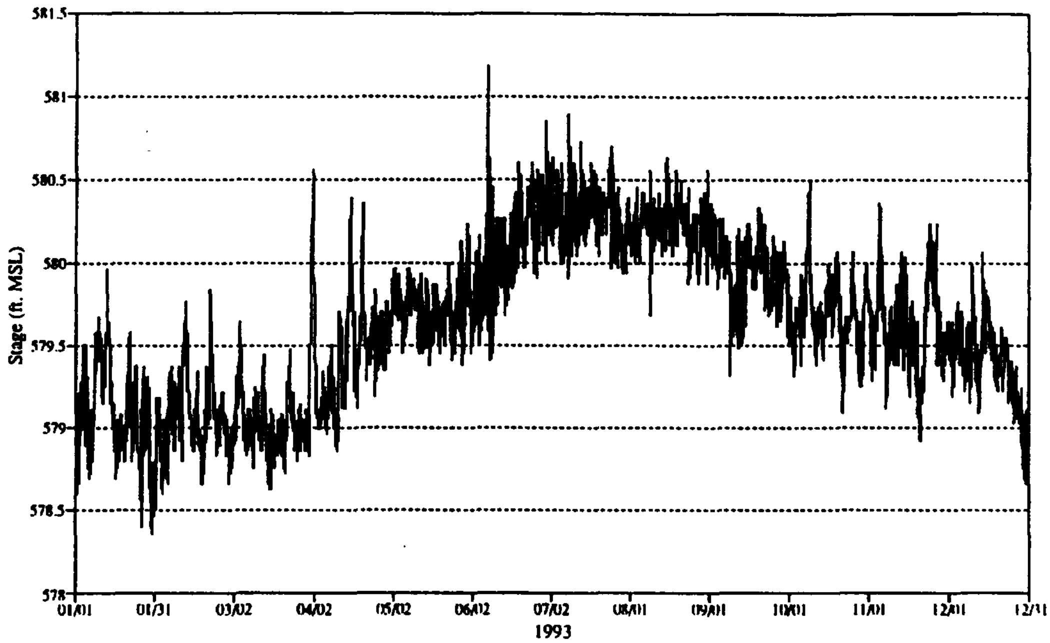
LAKE MICHIGAN CONCEPTUAL SURFACE WATER MODEL

Waukegan Manufactured Gas & Coke Plant Site

Figure 8-C-3

Lake Michigan Lake Levels

Milwaukee Harbor Coast Guard Base Gage



Waukegan Harbor Vs Milwaukee Harbor